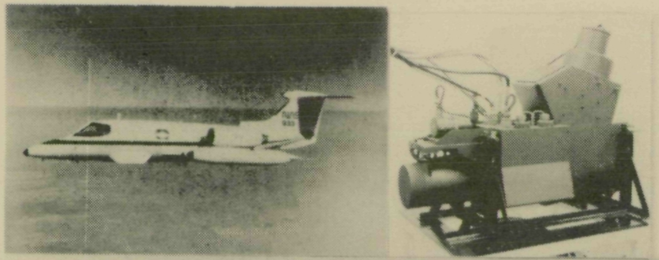
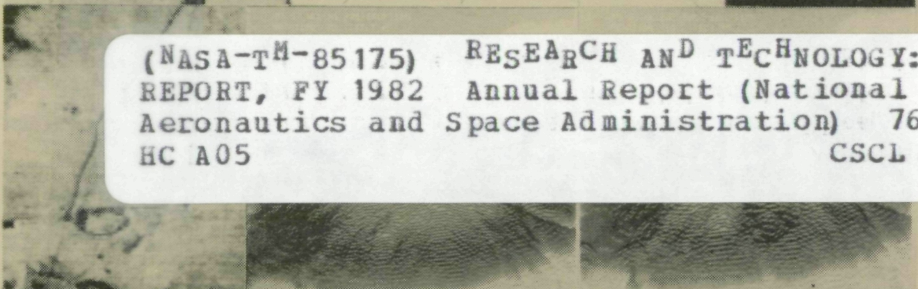
RESEARCH and TECHNOLOGY

NASA
National Aeronautics and
Space Administration

National Space Technology Laboratories

EARTH RESOURCES LABORATORY





(NASA-TM-85175) RESEARCH AND TECHNOLOGY: N83-22685
REPORT, FY 1982 Annual Report (National
Aeronautics and Space Administration) 76 p
HC A05 CSCL 05B Unclas
00/43 09782

ANNUAL REPORT **FY1982**

PREFACE

The purpose of this report is to present the major accomplishments of the National Space Technology Laboratories, Earth Resources Laboratory for Fiscal Year 1982.

The report includes program activities sponsored by the NASA Office of Space Science and Applications and special projects funded by other departments of the Federal government. All Laboratory activities directly support overall NASA goals and objectives.

This annual report is to be updated November 1 of each year. For additional copies, contact:

K.D. Cashion,
Earth Resources Laboratory,
National Space Technology Laboratories,
NSTL Station, Mississippi 39529
(FTS: 494-1930; commercial: 601-688-1930).

CONTENTS

INTRODUCTION

One of the many NASA earth resources remote sensing programs since the early 1970's has been the development of automated analysis techniques for satellite-acquired data. During this period there were very significant advancements achieved at the National Space Technology Laboratories (NSTL) by the Earth Resources Laboratory (ERL) in the generation and use of the following:

- Low-cost data analysis systems
- Flexible computer programs designed for expansion based on increased data applications
- An organizational structure interfacing a wide range of specialists and unique data with potential user communities
- Transferable NASA-developed technology for governmental and private organizations

A new level of effort has been initiated in FY1982 with a more in-depth look at remotely sensed data. Aircraft with high resolution sensors, operating on better defined wavelengths, provide detailed multispectral data to specialists who are familiar with multivariate classification techniques. Research programs are conducted without losing the potential for user applications: techniques are tested on economical computer systems with adaptable programs. Some of these research programs are available to the public from COSMIC: some are generated for particular data sets and specialized studies.

This Research and Technology Annual Report reviews the significant accomplishments at NSTL/ERL during FY1982. The report demonstrates ERL's continued advances in sensor utilization, software development, and data analysis techniques. These techniques increase NASA's ability to acquire and use remotely sensed data in specialized areas of research. Cooperative programs continue to test and relate problem/solution analysis to user communities. The FY1982 report is divided into 6 sections that represent the NSTL/ERL's remote sensing program.

- SENSOR SYSTEMS
  - Thematic Mapper Simulator
  - Thermal Infrared Multispectral Scanner
  - Advanced Sensor Design Studies

SENSOR SYSTEMS

“PAGE MISSING FROM AVAILABLE VERSION”

“PAGE MISSING FROM AVAILABLE VERSION”

THEMATIC MAPPER SIMULATOR

The Thematic Mapper Simulator (TMS) was developed by NSTL in late 1979, flown initially in May, 1980, and became operational the following October. Since that date, more than 125 data acquisition missions have been conducted.

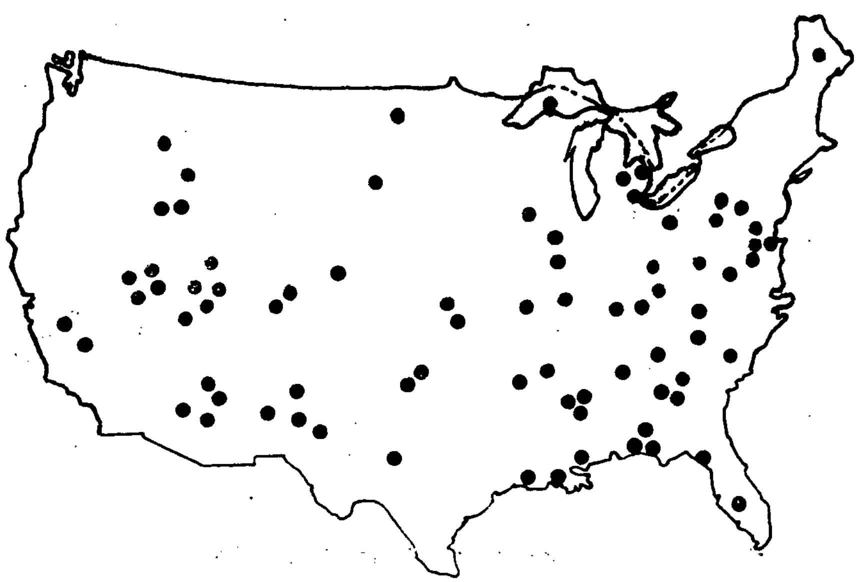
During FY82, NSTL's Lear 23/TMS was used for 54 data acquisition missions. The resulting TMS data were provided to 26 investigators at various NASA field centers, other government agencies, and universities. TMS data have enabled users to evaluate the applicability of 30 meter ground resolution and the 7 Thematic Mapper spectral bands for many different remote sensing applications in anticipation of Landsat 4 TM data acquisition. Additionally, TMS data have allowed users to develop data handling and analysis techniques prior to the availability of data from the satellite-borne system.

The large volume of TMS data acquired in response to investigation requirements has produced significant streamlining of the NSTL's quick-look data analysis system, referred to as the ERL System III. This capability, based on a Perkin-Elmer 3241 mini-computer, allows investigators and sensor engineers to perform preliminary data analysis within minutes of the arrival of a TMS data tape at the computer facility. An 11-channel computer-controlled decommutation system allows all 7 TMS channels to be placed into a computer-compatible format in real time: a 7 minute data run can be decommed in 7 minutes.

Data from any 3 channels can be displayed on an image display device while decommutation is in progress. This device represents the primary quick-look data analysis tool. Sensor engineers can verify data quality for all 7 channels, while investigators can verify acceptable test site coverage and the absence of unacceptable cloud cover. While data are being displayed on the image display device, all pertinent flight parameters from the aircraft inertial navigation system are simultaneously updated and displayed on a flight system status panel. These parameters include: ground speed, pitch and roll angles, latitude and longitude, and instrument parameters such as gain, scan rate, calibration source temperatures, and scan line count.

Upon completion of the quick-look analysis, the data are reformatted into the ELAS format and placed in storage on the appropriate investigator's disk pack. In the case of non-NSTL users, the data are initially placed on a disk pack and then are copied to computer-compatible tapes in a format containing 800, 1600, or 6250 characters per inch, depending upon the user's capabilities for reading the tapes.

Since the Landsat 4 TM is now operating, the future requirements for the TMS will be directed at non-simulation activities. Although a certain amount of residual simulation work exists, most new flight requests are directed at higher spatial resolution applications. Spatial resolution of the system is a function of aircraft altitude. A fixed Instantaneous Field of View (IFOV) of 2.5 milliradians allows the system to provide target resolutions of 2.5 feet for every 1,000 feet of aircraft altitude. Velocity to height ratio capabilities of the aircraft/TMS dictate a maximum resolution of 5 meters, with a minimum resolution of 33 meters. Capabilities are continuously variable between these two extremes. These capabilities promise to insure continued utilization of the TMS even though its primary mission, the simulation of Landsat 4 TM data, was concluded upon the successful launch and verification of the satellite system.



Distribution of TMS data acquistion sites across the U.S.

SENSOR SYSTEMS

THERMAL INFRARED MULTI-SPECTRAL SCANNER

As a result of NSTL/ERL's experience with airborne sensors with respect to the TMS and the Advanced Poppy Detection System, NSTL was assigned the responsibility in FY1980 for designing and developing another airborne system - a Thermal Infrared Multispectral Scanner (TIMS) - as a definition tool for future satellite-borne, geology-oriented sensors.

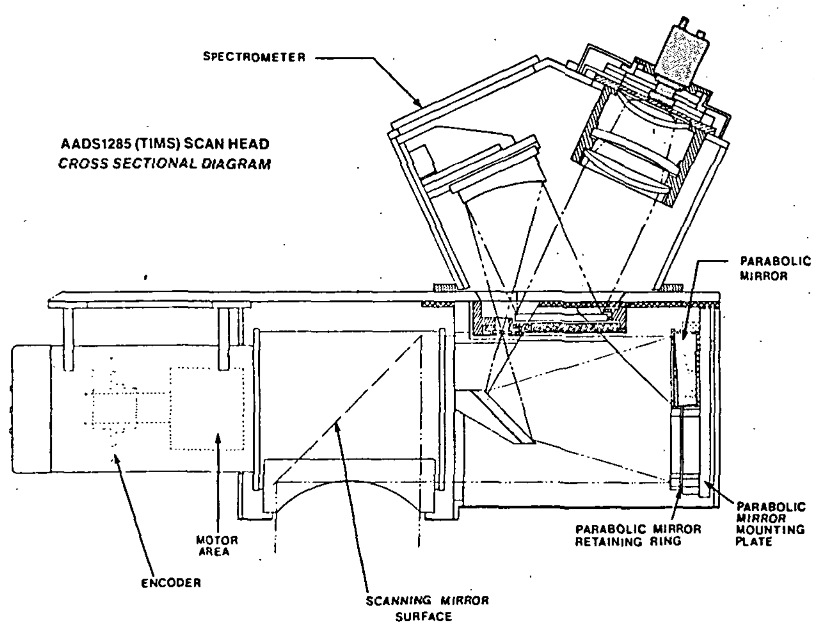
The TIMS is a conventional electro-optical scanning device which produces 6 discrete data bands over the 8-14μ thermal infrared portion of the electromagnetic spectrum. Development of this system continued during FY1981, with parts delivery and subsystems checkout being the major milestones accomplished.

TIMS utilizes scanner technology developed during the cooperative illegal crop detection project with Mexico, sponsored by the US Department of State. The scanner primary optics design is identical to that used in Mexico, while the spectrometer design is unique for the thermal infrared application.

The TIMS was delivered to NSTL in May, 1982. The system was not operational at delivery, even though all laboratory acceptance tests at the manufacturer's facility (with the exception of the NE delta T Performance of one of the 6 data channels) were satisfactory. The flight acceptance test revealed a number of serious problems which would require several months of troubleshooting and testing to make the system useable. The funds available for these activities were limited, forcing NASA to conclude the development contract and bring the system in-house for the additional work.

The following deficiencies were noted at delivery-

1. Channel 6 was out of specification for NE delta T.
2. Instabilities in the internal calibration sources existed.
3. The heated calibration source had inadequate drive capability in the thermal environment at 40,000 feet.
4. The 400Hz power source on the aircraft produced excessive interference on all data channels.
5. Mechanical interference between the scan head and aircraft structure existed.



TIMS SCAN HEAD CROSS-SECTION

The TIMS remained in the laboratory at NSTL from May 14 until July 18 while repairs for the numerous problems were designed and implemented. The mechanical interference problems were solved by rebuilding/downsizing or relocating those scan head protrusions which interfered with aircraft structure. All electrical problems, with the exception of the out-of-spec condition of channel 6, were corrected by redesign of various circuits or replacement of defective electronic components. The 400Hz noise problem could not be duplicated under laboratory conditions, so the solution to this problem was deferred until the flight test program was initiated.

During the laboratory calibration tests which followed the repairs and which were required to establish the radiometric and spectral calibration of the instrument, additional design deficiencies were noted, any one of which could have produced an unuseable condition for the sensor. The spectral response of channel 6, specified to be 11.2-12.2 micrometers, was measured at 11.2-11.5 micrometers. This explained the lack of sensitivity experienced in channel 6 during acceptance testing. Numerous tests were conducted on individual optical components which could contribute to this shortening of bandwidth, but no irregularities were found in the test results. Continued experimentation into this problem was delayed until after the flight test program. A dewar vacuum loss also occurred unexpectedly during laboratory testing, but the vacuum was quickly reestablished. This event provided an opportunity to inspect the interior of the dewar and the detector array. The window which covers the array was found to be in poor condition, and a new one was ordered.

Secondary noise sources were identified as the preamplifier assembly and the cable leading from the detector array to the preamp circuit board. Both the cable and the preamp circuit board were rebuilt, resulting in much improved noise rejection. The enclosure for the preamps was also rebuilt to reduce preamplifier EMI susceptibility.

The TIMS underwent a series of flight tests during the last two weeks of July. The 400Hz noise problem was again observed and was eliminated by replacing the aircraft power inverter. As the noise source was eliminated, a second source, masked on previous flights by the magnitude of the 400Hz noise, appeared. The design of the liquid nitrogen dewar allowed microphonic noise, generated in response to aircraft vibration, to be produced. Because the basic design of the dewar could not be altered, low temperature shims were inserted between the inner and outer cases of the dewar. This addition reduced the microphonic noise to a tolerable level. Remanufacturing of the dewar, with a different design specification, will be required to completely solve the problem.

The final flight in the test program yielded acceptable data, and the aircraft was dispatched in late August to acquire data over a number of test sites in the western U.S. Data were acquired over Oregon, Nevada, New Mexico, California, Colorado, and Utah during a 9 day period. All data flights yielded good results.

The TIMS was delivered to JPL on September 1, 1982, for laboratory calibration testing. This testing was primarily radiometric in nature and was completed on September 20. Upon return of the system to NSTL, laboratory testing continued with a second detector/dewar assembly. These tests continued through the end of the fiscal year.

During FY83, the TIMS is expected to enter into a fully operational mode, in which data will be supplied not only to NSTL and JPL, but to other NASA centers, other federal agencies, and to universities, with flights being made by the Lear 23 on a reimbursable basis.

SENSOR SYSTEMS

ADVANCED SENSOR DESIGN STUDIES

During FY82, Center Director's Discretionary Funds totalling $42,000 were obtained for the purpose of performing Advanced Sensor Design Studies. The funds were directed at two distinct areas of study:

1. Design of a Variable Resolution Multi-Linear Array Pushbroom Scanner Prototype for the Lear 23
2. Preliminary design of 3 advanced sensor candidates:
   - Active (target-illuminating) Multispectral Scanner
   - Scanning Terrain Profiler
   - Microprocessor Controlled Field Spectrometer

Each of these design studies was concluded on September 30, 1982. Each yielded results which either verified initial ideas relative to the possibilities of fabricating the subject devices or produced conclusions that the concepts were beyond the current fiscal and manpower limitations of the laboratory By far, the variable resolution MLA Prototype design produced the most positive results. This design will yield a workable prototype scanner during FY83 and sufficient knowledge of design tradeoffs to produce a calibrated flight system in FY84.

Design of the optical system including foreoptics, the spectrometer assembly, and the mechanical housing was undertaken in detail during the past year. The electronics design, which will incorporate the aircraft inertial navigation system outputs, will be accomplished in early FY83. Flight testing of the Prototype is slated for September, 1983. Two of the operational capabilities included in the design are:

1. Variable focal length foreoptics - This feature will enable the system to provide ground resolvable spot sizes over a range of 5-30 meters from an aircraft altitude of 40,000 feet above terrain. By decreasing aircraft altitude, ground resolution of 1 meter may be obtained.
2. Off-nadir viewing - This feature will allow two of the system's three linear array cameras to simultaneously acquire fore-and-aft pointing data for use in developing electronic topographic relief measurements.

Upon completion and testing of the proof-of-concept Prototype and a thorough evaluation of data applicability for MLA simulation, the Prototype will be modified as required to become an operational sensor within NSTL's inventory.

The Advanced Sensor Design Studies represented new R&D initiatives for NSTL in FY82. They consisted initially of assessments of laboratory utilization potential for each of the candidate systems, followed by detailed design efforts to bring each candidate, if feasible, to a point where final fabrication drawings could be made. The design phase will be followed in FY83 by the selection of one candidate for fabrication.

The basic considerations projected into each design included aircraft (Lear 23) suitability, mission objectives, cost, and practicality of the task within the fiscal and manpower resources available. The results of the individual design efforts are summarized as follows:

1. Active (target-illumination) Multispectral Scanner - Present operational passive multispectral scanner systems use the sun as the target illumination source for the reflective bands. In the spectral region of 0.4-1.1 micrometers, the sun provides an irradiance on the ground of approximately 800 watts per square meter at an air mass of 1. Thus, a 5 meter ground element is irradiated with about 20,000 watts. The Lear 23 has approximately 14,000 watts of electrical power available for use by the active scanner system. Assuming system power requirements, exclusive of the illumination source of 1,000 watts, the remaining 13,000 watts could be used for the illumination source. Research indicates that approximately 10% of that power, or 1,300 watts, could be converted into ground irradiance in the 0.4-.1.1 micrometer spectral region without significant difficulty. Current silicon detectors do not have the sensitivity to provide adequate signal-to-noise ratios in response to ground irradiance levels as small as this.

The solution to this problem can be directed at the illumination system, the detection system, or both. The illumination system can be improved in 2 ways: (1) The optical transmission system can, through research and experimentation, be improved to potentially allow 20% of the 13,000 watts available to be converted into ground irradiance. This would double the target illumination, but would still not provide the detectors with adequate reflected energy. (2) The second improvement in the illumination system consists of making additional power available to the xenon arc lamp. This can be done by adding any one of a number of commercially available, wind-driven power generators to the aircraft. This unit, mounted beneath the fuselage, could easily triple or quadruple the 13,000 watts currently available. The disadvantages of the system are the additional weight, the decreased aircraft performance, and the increased complexity of the xenon lamp cooling system.

There are many areas of potential research for the detection system. Avalanche photo-diodes have demonstrated the possibility of significant sensitivity improvements, although these improvements come at the expense of detector stability. Thermal control of the photo-diodes is also required. Linear array detectors offer the advantage of longer dwell times on the target, converting this directly into increased signal-to-noise ratios. This benefit may be negated, however, because longer dwell time is produced only if the target is illuminated during the total duration of the dwell period, which is not the case with the active scanner.

2. Scanning Terrain Profiler - This device was originally envisioned as a moderate power (5-10 watts) GaAs or HeNe CW laser coupled to a low speed scanning mirror to produce an accurate topographic profile of the terrain being overflown. The Profiler would be synchronized with a conventional Multispectral Scanner (TMS or TIMS), and the profiler data output would be sampled once for each data pixel of the MSS. Thus, the Profiler would have the same spatial resolution as the MSS and would provide one topographic measurement for each MSS pixel. Even though the spatial resolution of the Profiler could be made much better than the MSS, the desire to allow the Profiler, through on-board data processing, to serve as an auxiliary data source for the MSS dictated the planned sampling technique. The Profiler sample could represent either the relief of a single 1-foot-diameter circle in the center of each MSS pixel, or the average relief of a 1-foot-wide line across the center of each MSS pixel.

   Although a significant amount of research must be performed to perfect the synchronization and control electronics, the task appears to be feasible. The only significant disadvantage to the project is the fact that the MLA Simulator effort, which is reported in a separate Discretionary Fund Report and which is further developed than the Scanning Profiler, should also be able to provide topographic information through the planned fore-and-aft viewing capability, although not as a direct output. Significant data processing software development to convert the stereo-viewing photographic interpretation technique into an electronic technique will be required.
3. Microprocessor Controlled Field Spectrometer System - This candidate system is by far the simplest of the three design studies. The main requirements of spectral coverage, Variable Field of View (both spatial and spectral), real-time read out, and portability can be met. Several possibilities for the instrument design exist and will require inputs from potential users regarding system design criteria. Fortunately, the commercial manufacturers of field spectrometers have advanced the state-of-the-art significantly during the past year, and the competitiveness of the market may produce a useable system, meeting all of the operational criteria before the subject system design is committed to fabrication.

Based upon prevailing laboratory and agency needs, the practicality of fabricating the devices and the growing availability of similar devices from industry and other NASA centers, it appears that only the Active Multispectral Scanner design will be pursued in FY83. This effort will be limited to research into the solution of stated problem areas. Actual fabrication of a device will not be attempted in FY83.

- DATA ANALYSIS PROGRAMS
  - Automatic Segment Matching Algorithm
  - Contextural Information Classifier
  - Geobased Information System

DATA ANALYSIS PROGRAMS

Page Intentionally Left Blank

AUTOMATIC SEGMENT MATCHING ALGORITHM

The algorithm for automatically registering USDA/SRS digitized segments to Landsat data was generated, tested, evaluated, and implemented on the USDA/SRS EDITOR System during FY1982. The algorithm was further developed and refined beyond the status of AgRISTARS Report DC-Y1-04211 (NSTL/ERL Report No. 201). Several acceptance tests were implemented and a complete error analysis performed. The algorithm was evaluated using 6 Landsat scenes of Kansas and Missouri (comprising 121 segments). The Department of Agriculture required an algorithm with 1/2-pixel accuracy. Based on a 57-meter resolution cell size and the results listed in the summary table below, the algorithm met the requirement.

The software was implemented on the USDA/SRS EDITOR System during FY1982. USDA/SRS personnel were trained in the use of Automated Segment Matching Algorithm (ASMA) and are operationally using it in 6 states. The theory, test, and evaluation results are documented in AgRISTARS Report DC-Y1-04325 (NASA/ERL Report No. 209).

SUMMARY OF ASMA RESULTS

Total segments tested - 121
Total segments accepted - 90
Row RMS - 18.86 meters
Column RMS - 25.21 meters
Total RMS - 31.62 meters

Depicted in plate 1 is a typical USDA/SRS segment registration which represents the original whole area registration and the localized fit after using the ASMA algorithm.

CONTEXTURAL INFORMATION CLASSIFIER

A Contextural Information Classifier was implemented on an array processor to use spatial information in the classification process. Test and evaluation will be completed in FY1983.

DATA ANALYSIS PROGRAMS

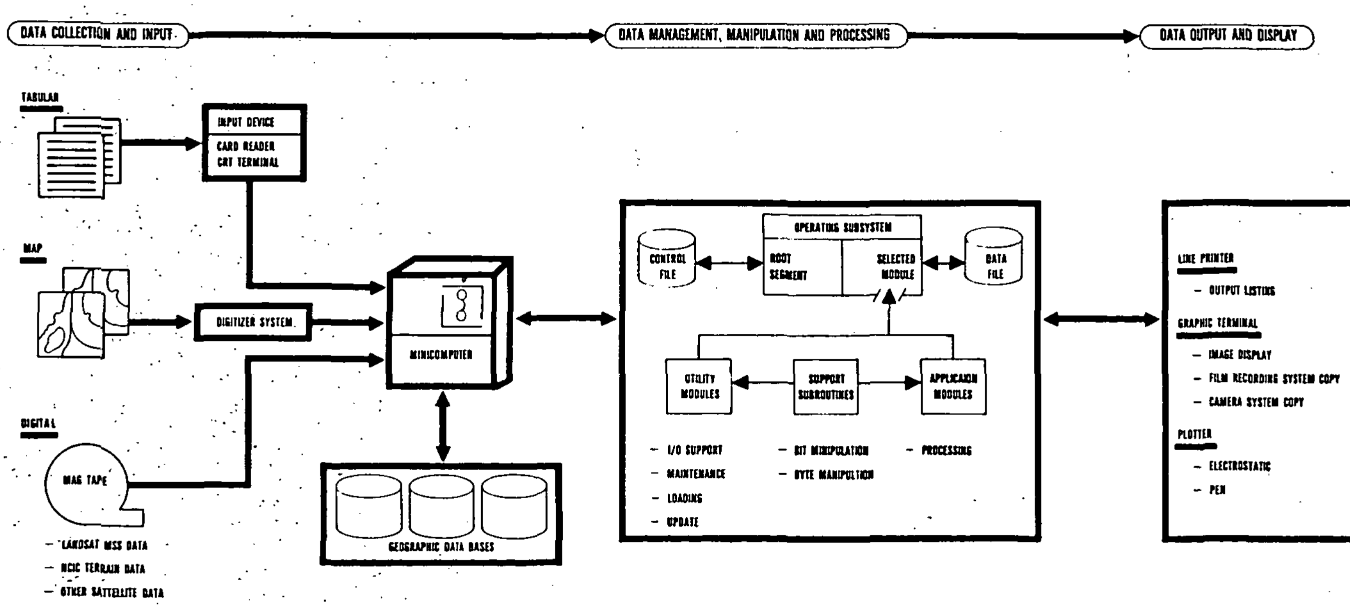
GEOBASED INFORMATION SYSTEM

The diverse and complex requirements of resource managers accentuate the need for the development of Geobased Information Systems (GIS's). The NASA/NSTL/ERL has developed several computer programs and procedures within the framework of a computer-oriented information system for the processing and analysis of data from disparate, geographically oriented base maps and from remote sensor aircraft and satellite systems. The capability to manipulate, store, analyze, display, and disseminate the large volumes of data in these data bases has evolved through research efforts at the ERL and has resulted in the development of an ERL Geobased Information System. The general concept of a GIS is illustrated in figure 1.

The functional aspects of topographic application programs in the ERL GIS system involve using National Cartographic Information Center (NCIC) digital terrain data obtained for both the 1:250,000 and 1:24,000 scale USGS maps. New topographic data processing capabilities include the use of the Digital Terrain Elevation Models (DEMs). The NCIC produces a DEM for each 7.5-minute 1:24,000 scale quadrangle at a grid spacing interval of 30 meters. Since these data are aligned with UTM grid lines, there is no UTM orientation correction, as required in the TOPO programs, for processing the 1:250,000 scale data.

To operate the DEM software module, a multifile DEM tape is required from the NCIC. The DEM data are reformatted, filtered, mosaicked, and then output to a disc file. At this time, the RL90 software module can be used to rotate and align the data to a north-south direction. A further capability has been developed in the software module RECE which allows a user to resample 16-bit NCIC topographic data or 8-bit ELAS (Earth Resources Laboratory Applications Software) data using either the nearest neighbor or bilinear interpolation technique.

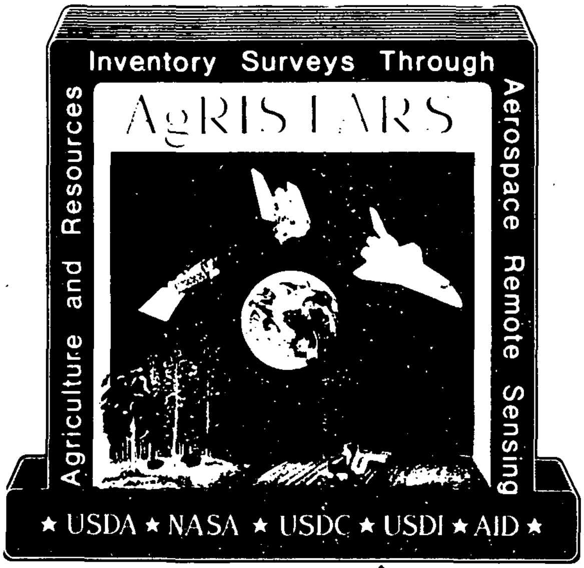
FIGURE 1



GENERAL CONCEPT OF A GEOBASDED INFORMATION SYSTEM

Page Intentionally Left Blank

- AGRICULTURE AND RESOURCES INVENTORY SURVEY THROUGH AEROSPACE REMOTE SENSING (AgRISTARS)
  - *Land Cover Area Estimation*
  - Land Cover Information Systems
    - Geographic Information Systems
    - Land Cover Change Detection
    - Map Product Accuracy
  - Thematic Mapper Procedure Development



AGRICULTURE AND RESOURCES INVENTORY SURVEY THROUGH AEROSPACE REMOTE SENSING (AgRISTARS)

AgRISTARS is research program designed to benefit agricultural concerns by using aerospace technology. The focus of the program is to develop satellite remote sensing techniques for a variety of practical purposes related to agriculture. AgRISTARS is a joint program of the United States Departments of Agriculture (USDA), Commerce, Interior, State (Agency for International Development), and NASA.

The primary aims of AgRISTARS are the development of a system to provide early warning of conditions which affect crop production and the development of techniques for more accurate commodity production forecasts, both foreign and domestic. The program has other areas of interest including classification of land use, estimating soil productivity potential, assessing conservation efforts, and detecting farm-related pollution.

NSTL/ERL participation in AgRISTARS involves two major projects: (1) Domestic Crops and Land Cover (DCLC) and (2) Conservation Inventory. As the NASA "lead" center for the DCLC project, ERL researchers direct their efforts in automatic data classification and estimation of land cover with emphasis on major crops. Data from Landsat MSS and advance sensors such as Thematic Mapper and Synthetic Aperture Radar data are used. These efforts also include research in scene-to-scene and scene-to-map registration; land cover classification/mapping algorithms; land cover area estimation; Geographic Information Systems development; and the development of advanced TM and SAR information extraction procedures.

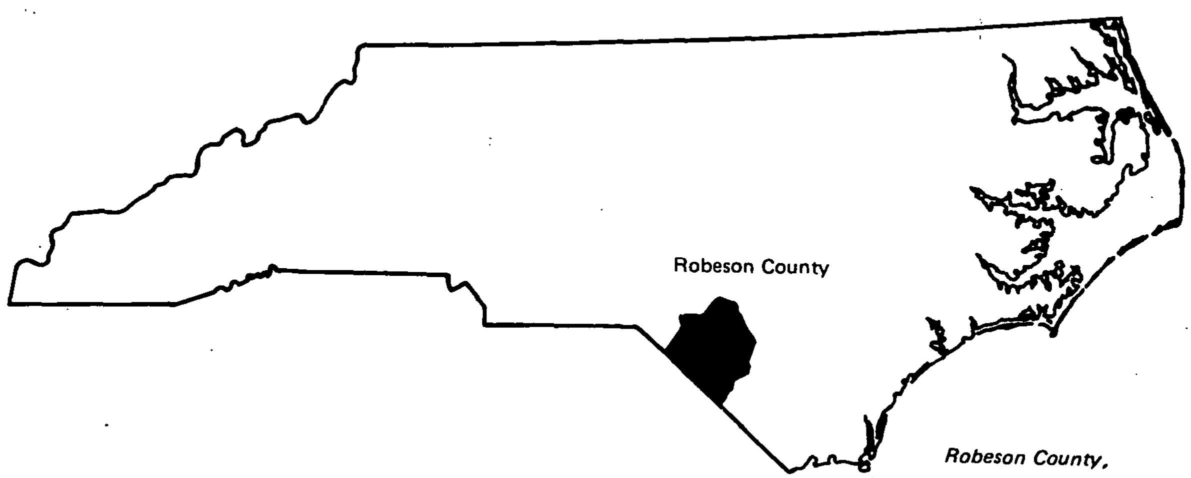
In the Conservation Inventory Project, ERL researchers are using study areas that contain various conservation practices to develop remote sensing techniques for inventorying such practices and to determine areas where conservation practices are needed.

LAND COVER AREA ESTIMATION

Accurate crop area estimates have been provided for some time by the United States Department of Agriculture through a nationwide sampling procedure. This area frame sampling procedure involves careful enumeration of planted crop types or planting intentions for fields within given sampled land areas (referred to as segments). Information collected during the June Enumerative Survey (JES) serves as useful ground truth data for remote sensing surveys and is the point of commonality between USDA and NASA/NSTL/ERL efforts in the AgRISTARS Domestic Crops/Land Cover project in the area of land cover inventory and mapping. The land cover area estimation task was designed to apply the JES sampling procedure to all land cover types while defining the adequate sample size for total land cover mapping. An additional objective is to determine the effect of stratifying fields according to soil survey information for the purpose of improving the accuracy of sensor-derived land cover maps.

During FY1982 a multidate Landsat data set of Robeson County, North Carolina, was constructed using Landsat MSS data from June 11, July 17, August 4, and September 9, 1980. Land cover information is available for 175 JES segments from the 1980 growing season. Soil information was extracted for each field within these 175 segments from 1:20,000 scale soil survey data of Robeson County. Definite correlations have been observed between certain soils, land forms, and land cover types. Tobacco fields occur only on well-drained soils while the distinct Carolina Bay soil land forms, when cleared of native forest, are almost exclusively planted to soybeans.

Accuracy assessment and area estimation will be conducted during the next fiscal year. Adequate segment sample size will be determined, and the value of introducing soil information into the Landsat data analysis process will be evaluated in terms of possible improvement in the precision of land cover area estimates. The final report will be released in FY1983.



Robeson County, North Carolina, AgRISTARS test area

AgRISTARS LAND COVER INFORMATION SYSTEMS

The land cover information systems task consists of three subtasks: (1) the Geographic Information System (GIS) application to inventory and monitoring, (2) the evaluation of land cover change detection techniques, and (3) the production and evaluation of map products.

GEOGRAPHIC INFORMATION SYSTEMS

The first of these subtasks has the objectives of (1) developing procedures for the efficient input and interfacing of remotely sensed data to GIS's and other digital data files, and (2) evaluating the utility of GIS information derived from remotely sensed data for specific applications.

During FY1982, activities began with the Soil Conservation Service (SCS) to determine how ELAS could be integrated with a GIS that is tailored to SCS needs. In addition, three study areas were selected for investigating the GIS implementation of the Universal Soil Loss Equation (USLE) as a means of identifying areas with high soil erosion potential. The three study areas are located in the Goodwin Creek Watershed in Panola County, Mississippi; Houston County, Alabama; and Upper Wakarusa River Watershed near Topeka, Kansas. The GIS implementation of USLE requires the building of a geographic data base containing land cover information derived from remotely sensed data (both Landsat MSS and TM will be evaluated), soils data, and topographic data for each study area.

As a first step in the generation of a geographic data base for the Upper Wakarusa River Watershed, a land cover classification was derived from two dates of Landsat MSS data. These data were collected in June and October, 1979, and overlaid to form an 8-channel data set. The SRCH automated signature development algorithm in ELAS was used to derive spectral signatures from the overlaid Landsat data.

Once signatures were developed, they were used to produce a 12-category classification of the data. The watershed boundaries were digitized from maps, and only those land covers that fell within this area were extracted from the Landsat classification. (See plate 2.) An areal assessment was made by class for all land cover categories identified within the watershed. (See table 1.) The total 149,420 acres computed for the Landsat classification represented a less than 3% difference in acreage in comparison with the published land area of 154,000 acres.

Soils maps for the Upper Wakarusa River Watershed have been digitized, and slope data are being derived from both 1:250,000 and 1:24,000 scale topography maps. These same types of data have also been processed for the Goodwin Creek, Mississippi, study area and have been acquired for the Houston County, Alabama, study area. It is anticipated that data bases for all three study areas will be completed, and the GIS application of the USLE will be evaluated during FY1983.

TABLE 1

AREAL ACREAGE ASSESSMENT BY CATEGORY FOR UPPER WAKARUSA RIVER WATERSHED, KANSAS

CATEGORY (CLASS)	ACRES	% OF TOTAL
FOREST LAND	22,048	14.76
PERMANENT VEGETATION	86,266	57.73
RIPARIAN VEGETATION	1,121	.75
SUMMER FALLOW	2,487	1.66
ROW CROPS	19,709	13.19
WINTER WHEAT	11,120	7.44
URBAN/BUILT-UP LAND	680	.45
MEDIUM DENSITY RESIDENTIAL	2,921	1.96
OTHER URBAN LAND	745	.50
INERT MATERIALS	172	.12
BARE SOIL	1,155	.77
WATER	457	.31
OTHER LAND COVERS	539	.36
TOTAL	149,420	100.00

CHANGE DETECTION

Change Detection efforts at NSTL/ ERL have concentrated on the development and testing of methods for processing multidate Landsat MSS data to measure surface cover changes. The characterization of these radiometric differences between spectral data sets into meaningful measures of land use conversion is being carried out in a number of study areas covering a variety of environments. Table 2 shows how Landsat-identified land use conversion compares with digitized ground data for a 30 by 60 minute area in east central Louisiana.

In support of the AgRISTARS Program's Domestic Crops and Land Cover Project, the design emphasis has been to structure research products to update the area sampling frame. This area sampling frame is used by USDA's Statistical Reporting Service as the basis for estimating yearly crop production. Plate 3 shows how Landsat MSS-derived information on land use conversion could support this process based on basic areal reference unit. Figures 1 & 2 of plate 4 gives a sequential view of land use conversion in southwest Kansas.

Detailed areal ecosystem/habital conversion information, such as that shown in figure 3 of plate 4 could be used in descriptive models for determining what effects such changes have on our environment. Biophysical parameter data (i.e., energy flow, CO_2/O_2 exchange, the heat budget, etc.) could be acquired from ground-based studies of radically altered ecosystems. The product from comparing these relationships could be combined with satellite-derived areal data of the respective ecosystems.

MAP PRODUCTS

The AgRISTARS Map Product/Map Accuracy subtask had two objectives: (1) to investigate ways in which maps could be produced from the use of USDA's existing Statistical Reporting Services (SRS) ground truth data, and (2) to develop statistical estimates of the fidelity (accuracy) of the maps when compared to the ground.

An example of a map product is presented in plate 5, which represents a geographically registered (UTM coordinate system) computer-implemented land cover classification of Sedgwick County, Kansas. The large circle to the right of the center is the city of Wichita, which has been divided into commercial/industrial (red/ yellow/orange) and residential (green) sections. Two airport complexes can be distinctly seen to the left and right of the city. The other colors represent a total of 13 land cover types, based on 22 ground truth areas. Three other counties were also included in the study. Products generated included electrostatic black and white plots (at various scales), colored plots, photographic prints/viewgraphs, and simple line printer output.

Numerous accuracy indicators were examined, such as "jackknifing" and the more conventional approaches (acceptance theory, analysis of variance, object accuracy as developed by Hillden). The key element in evaluating accuracy was to incorporate SRS ground truth in the accuracy indicator as explained in NASA/ERL Report No. 216, "Determining Map Accuracy based on the User of USDA Statistical Reporting Service June Enumerative Survey Segment Data."

TABLE 2

ACCURACY RESULTS

Data Source Argument		%
Error	Commission	2.8
	Omission	1.1
Agreement	Change	9.1
	No Change	87.0
Total % Correct		96.1

THEMATIC MAPPER PROCEDURE DEVELOPMENT

During FY1982 Thematic Mapper Simulator (TMS) data sets for 4 study areas were analyzed at NASA/ERL in conjunction with the AgRISTARS program, TM Procedure Development. They are: (1) Mississippi Study Area, (2) North Dakota, (3) Colorado, and (4) South Carolina. Results of the analyses for the first 2 study areas are detailed in NASA/ERL Reports No. 202, "Analysis of Thematic Mapper Simulator Data Acquired During Winter Season Over Pearl River, MS, Test Site," and No. 204, "Analysis of Thematic Mapper Simulator Data Collected Over Eastern North Dakota." Final results for the other two study sites will be published during FY1983.

1. MISSISSIPPI STUDY AREA

Report No. 202 presents results of digital processing of aircraft-acquired Thematic Mapper Simulator (TMS) data collected during the winter season over a forested site in southern Mississippi. The purpose of the research was to investigate the utility of TMS data for use in forest inventories and monitoring.

Analyses indicate that TMS data are capable of delineating the mixed forest land cover type to an accuracy of 92.5%. The accuracies associated with river bottom forest and pine forest were 95.5 and 91.5%, respectively. These figures represent the performance for products produced using the best subset (choice of channels) for each forest cover type. (See table 3.) It was determined that the choice of channels had a significant effect on the accuracy of classifications produced and that the same channels are not the most desirable for all 3 forest types studied. Both supervised and unsupervised spectral signature development techniques were evaluated; the supervised methods proved unacceptable for the 3 forest types considered.

2. NORTH DAKOTA STUDY AREA

Report No. 204 presents results of the analysis of aircraft-acquired Thematic Mapper Simulator (TMS) data, collected in August, 1980. The principal purpose of the research reported was to investigate the utility of Thematic Mapper (TM) data through simulation in crop area and land cover estimates.

TABLE 3

Results of analysis showing statistically significant subsets of TMS data which produced the best results for each land cover type for the Mississippi Study Area. Numbers represent percent correct values associated with each land cover type/subset combination.

	TMS CHANNELS USED					
LAND COVER	1,2,3,4,5,7	2,3,4,5,7	2,3,4,5	2,4,5	3,4	4
Inert	96.19	96.19	96.67	97.62	95.24	35.71
Hay/Grass	89.16	95.18	94.58	94.58	97.59	0
Old Fields	91.95	89.93	71.14	63.09	47.65	0
Marsh	89.29	89.29	89.29	75.00	64.29	0
River Bottom	86.41	91.29	95.54	76.98	87.73	63.79
Mixed Forest	92.54	90.15	85.37	82.69	80.34	55.22
Pine	89.29	89.03	91.58	88.52	71.30	16.58
Water	100.00	94.59	95.24	99.35	96.91	20.35
Overall	91.13	91.90	92.30	85.01	87.06	38.42

Results of the analysis indicate that the 7-channel TMS data are capable of delineating the 13 crop types included in the study to an overall pixel classification accuracy of 80.97% with relative efficiencies for 4 crop types examined between 1.62 and 26.61. (See tables 4 and 5.) USDA's Statistical Reporting Service (SRS) considers any relative efficiency above 1.5 indicative of a significant reduction in variance and therefore an improvement in the technique used to derive land cover estimates.

Both supervised and unsupervised spectral signature development techniques as developed at NASA/NSTL/ERL were evaluated. The unsupervised methods proved to be inferior (based on analysis of variance) for the majority of crop types considered. Given the ground truth data set used for spectral signature development as well as evaluation of performance, it is possible to demonstrate which signature development technique would produce the highest percent correct classification for each crop type.

TABLE 5

RELATIVE EFFICIENCIES FOR FOUR CROPS

CROP	RELATIVE EFFICIENCY
Sugar Beets	1.62
Potatoes	26.61
Spring Wheat	4.37
Sunflowers	2.09

TABLE 4

PERCENT CORRECT CLASSIFICATION VALUES FOR NORTH DAKOTA 7-CHANNEL TMS DATA

LAND COVER CROP (SRS)	NUMBER OF PIXELS EVALUATED	SUPERVISED (MUCS)	UNSUPERVISED (WCCL)
1. Wasteland	190	57.78	73.34*
2. Sunflowers	91	47.37	84.72*
3. Spring Wheat	342	72.99	84.41*
4. Sugar Beets	56	69.85	75.98
5. Other Crops	46	87.90	82.86
6. Alfalfa	45	85.93*	63.97
7. Barley	38	91.67*	81.25
8. Potatoes	234	90.87*	68.23
9. Corn	53	90.68*	89.53
10. Beans	50	69.57*	35.81
11. Durum Wheat	50	91.53*	61.58
12. Summer Fallow	61	97.10*	89.86
13. Fall Fallow	268	90.46	86.93
"Overall"		80.97*	79.54

* Significantly better statistically than corresponding value for this cover type

3. COLORADO STUDY AREA

The purpose of the Colorado investigation was to relate forest canopy closure to Thematic Mapper Simulator (TMS) spectral data values for each of 7 bands. Percent canopy closure was determined from analyzed data of selected 25-acre plots within an area of the San Juan National Forest located in Colorado. The test area was a plateau with approximately a 9,000 foot elevation from which plots were chosen to represent the full range of canopy closure. The plots were selected with a "no slope" condition, as indicated from a USGS topographic map. This was done to minimize the effect of slope on the spectral response. The percent canopy closure was determined by interpretation of color IR photography. The vegetation was primarily Ponderosa pine.

Basic ELAS software modules were used to process the remotely sensed digital data. For each plot, the mean spectral response of each TMS band was determined. Then a linear correlation analysis of mean TMS response per band per plot versus percent canopy closure was executed. Table 6 indicates the results at the .01 significance level.

All correlations indicated a negative relationship between the variables, with band 5 showing the highest correlation. The following observations were made.

- As the surface cover of forest, measured as percent canopy closure, increased, spectral response decreased in all bands with the exception of band 4.
- The high spectral reflectivity of the background (dry soil, senescing grasses) probably contributed significantly to the response in all bands.
- It appeared that percent canopy closure, or forest cover, had more influence on TMS band 5 spectral response than on the response for any other TMS band.

4. SOUTH CAROLINA STUDY AREA

The South Carolina investigation supports the development of processing and analysis procedures for TMS data as a step towards understanding technique requirements for the analysis of TM data. Spring and winter TMS data were acquired over an area in Kershaw County, South Carolina, with a surface cover of predominantly pine forest and agricultural crops. Each data set was processed similarly for purposes of comparison. The processing technique involved the following sequence:

a. Development of supervised signatures on definitive sites of known surface cover
b. Statistical analysis of signature data from subsets of TMS channels to determine discrimination potential
c. Maximum-likelihood classification of data from selected subsets
d. Determination of classification accuracies and comparison of final products derived from channel subsets
e. Comparison of seasonal classifications

A detailed report of the data processing procedure and the results of the analysis will be generated in FY1983.

TABLE 6

TMS BAND

	1	2	3	4	5	6
Correlation	0.46-0.52μ	0.53-0.61μ	0.63-0.69μ	0.79-0.90μ	1.52-1.69μ	10.4-12.3μ 2.0
Coefficient	-0.757	-0.663	-0.666	-0.088	-0.797	-0.579

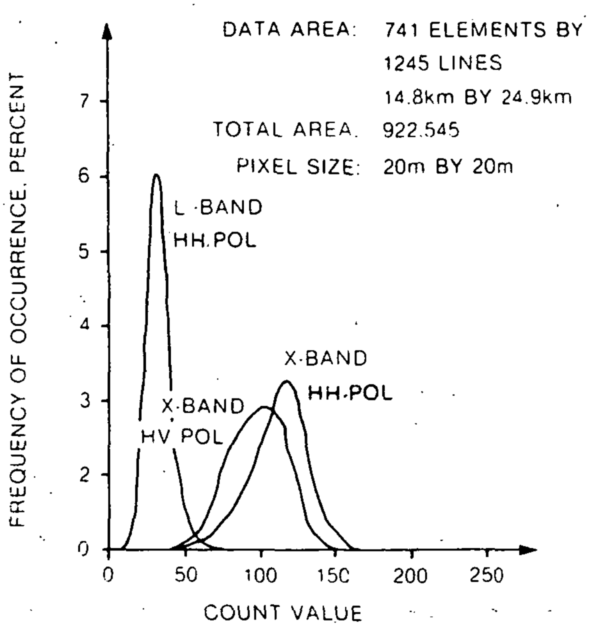
AgRISTARS SAR PROCEDURE DEVELOPMENT

During FY1982 a continuing effort was placed on data processing and analysis to assess the utility of using Synthetic Aperture Radar (SAR) data for crop and land cover estimation and mapping. X-band SAR data were acquired on March 10, 1981, for a truck garden area in Dade County, Florida; on June 15, 1981, for a rice paddy area in Acadia Parish, Louisiana; and on June 29, 1981, for a forest area in Kershaw County, South Carolina. The first step in the data processing task consisted of a visual inspection of the optically correlated image film, the digitization of image film, and the radiometric correction of the digitized data to reduce speckle noise and across-track stripping. The next step was to integrate (register or overlay) Landsat MSS data, Seasat L-band SAR data, and aircraft-acquired X-band SAR data for 3 polarizations (HH, HV, and VV) to form a multisensor data set for analysis.

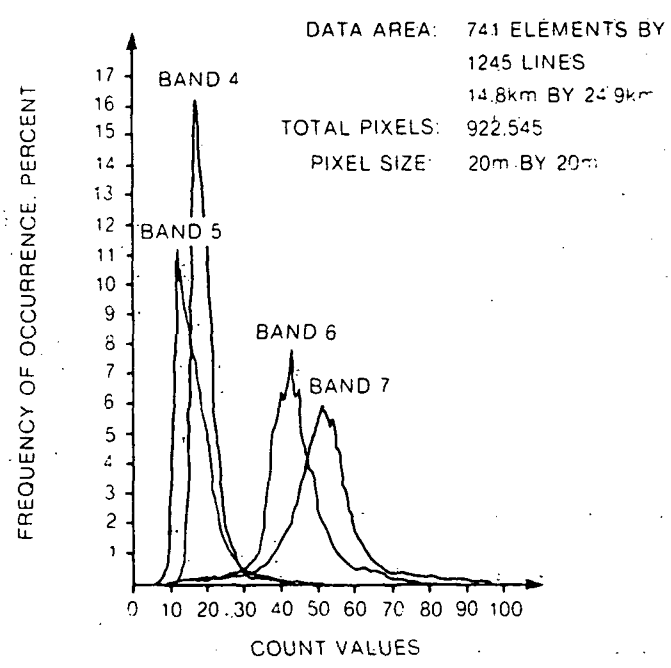
Subsequently, spectral signatures were developed and classified through multichannel pattern recognition using existing ELAS software. Ground data through field observation are being used to evaluate the classification.

The results show that the SAR-only data set contains low classification accuracy for several land cover classes. However, the combined SAR/MSS data show that significant improvement in classification accuracy is obtained for all 8 land cover classes. This is because those land cover classes that are very difficult to delineate using SAR data are less difficult to delineate using MSS data, and vice versa. These results suggest the usefulness of combined SAR/MSS data in forest-related cover mapping. The SAR data also detect several small special surface features that are not detectable by MSS data.

In the case of the Dade County multipass data set, preliminary results indicate that significant signature differences between North-South and East-West flight pass data are present to allow for the detection of row crops. The results of data analysis evaluation will be reported in a later report.



HISTOGRAM OF SAR DATA



HISTOGRAM OF MSS DATA

CONSERVATION INVENTORY

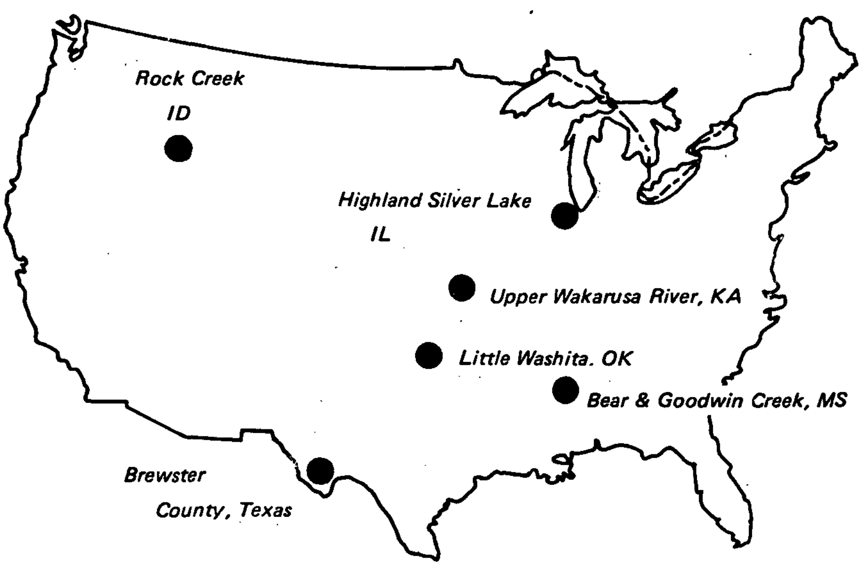
The purpose of the Conservation Inventory task was (1) to develop and evaluate remote sensing for the inventory of existing soil conservation practices and (2) to determine where conservation practices are needed for erosion control. Six study areas were selected to encompass a wide variety of conservation practices and/or needs.

- Bear and Goodwin Creek Watersheds in Mississippi
- Little Washita River Watershed in Oklahoma
- Upper Wakarusa River Watershed in Kansas
- Highland Silver Lake Watershed in Illinois
- Rock Creek Watershed in Idaho
- Brewster County in Texas

During FY1982, the emphasis was the development of baseline information through image interpretation of the conservation practices represented on several film types and scales and the processing of digital Landsat MSS and TMS data that have been acquired during the winter season (dormant vegetation) and the summer season (vigorous vegetation growth).

The use of scanner data, such as the Thematic Mapper and Landsat MSS, for determining areas where conservation practices are needed shows great promise when used in conjunction with soils and topographic data. The light-colored areas in plate 6 represent areas of sparse ground cover. The need for conservation practices is related to the degree of the erosion hazards that exist on the corresponding soils. The combination of this data (ground cover, soils, and topographic data in plate 6) will allow for the identification of areas where conservational practices are needed and for ranking them according to the areas' susceptibility to erosion.

However, many of the existing conservation practices, such as terracing, do not result in a sufficient change in the landscape to effect a change in the response of the scanners that are currently in orbit. Therefore, high resolution photography is being interpreted to determine the appropriate spatial resolution needed to resolve most soil conservation practices.



Conservation Study Areas

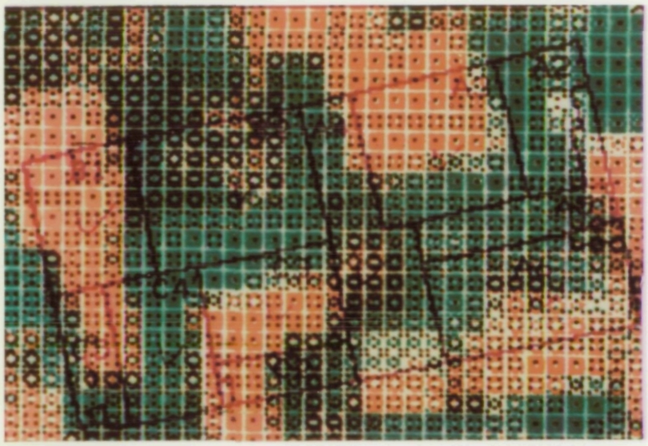
RESEARCH AND TECHNOLOGY COLOR PRODUCTS DEVELOPED DURING FY 82

TM Data acquired August 22, 1982 over Union City, Tennessee. Bands 2, 3, and 5 were used to simulate false color infrared photography.

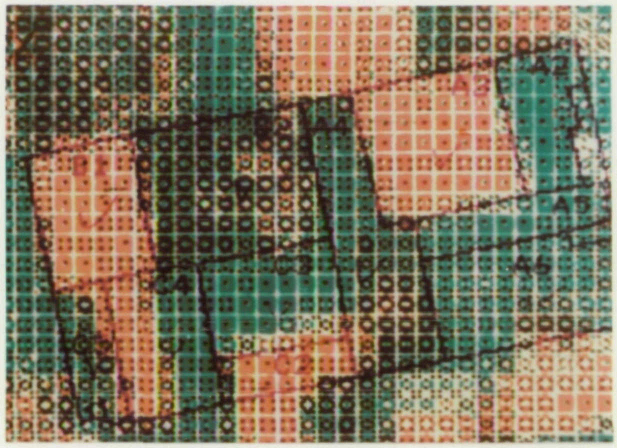
PLATE 1

AgRISTARS

DOMESTIC CROPS AND LAND COVER/SCENE-TO-MAP REGISTRATION TASK



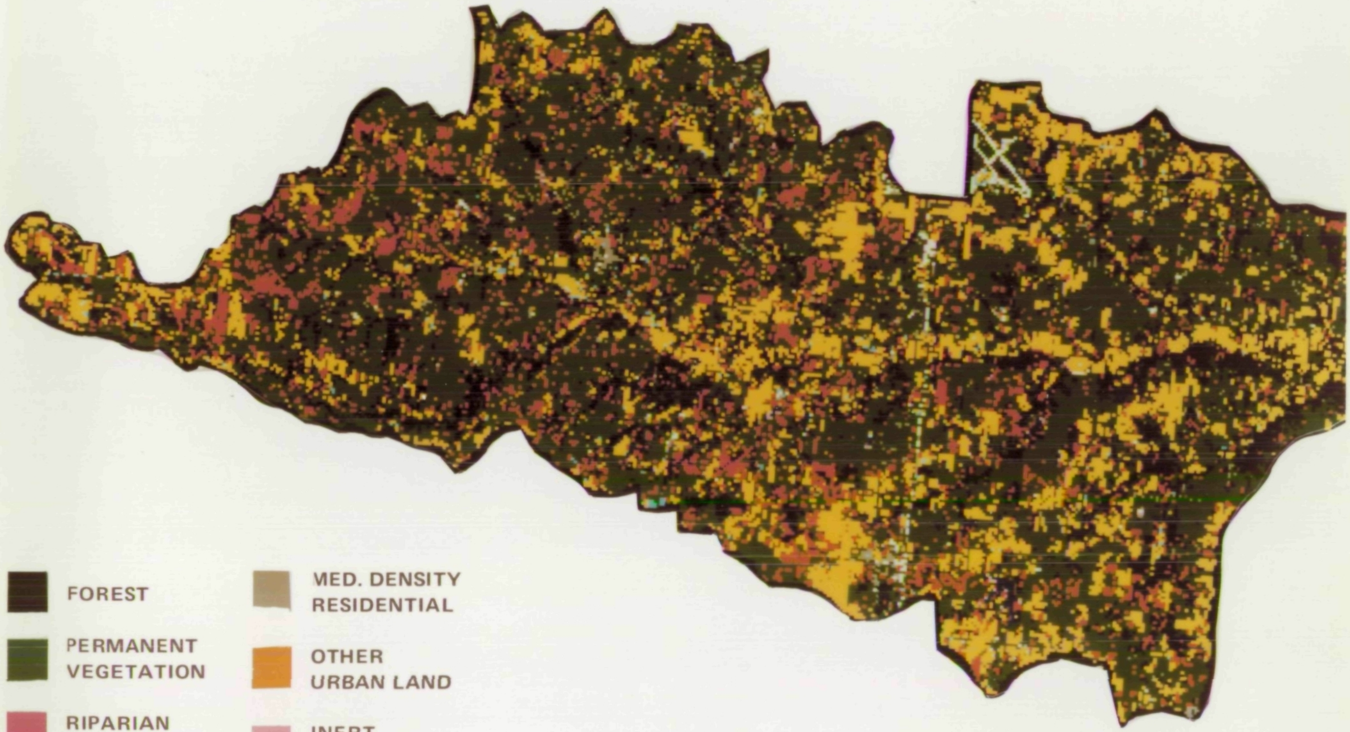
USDA/Landsat Data Overlay Before Applying the Automatic Segment Matching Algorithm (ASMA)



Overlayed Data After Applying the ASMA

PLATE 2

AgRISTARS GEOGRAPHIC INFORMATION SYSTEM TASK



- FOREST
- PERMANENT VEGETATION
- RIPARIAN VEGETATION
- ROW CROPS
- WINTER WHEAT
- URBAN/ BUILT-UP LAND
- MED. DENSITY RESIDENTIAL
- OTHER URBAN LAND
- INERT MATERIALS
- BARE SOIL
- WATER
- OTHER LAND COVERS

UPPER WAKARUSA RIVER WATERSHED FROM MULTIDATE LANDSAT MSS DATA (JUNE/OCTOBER, 1979)

This classification of a multidata set for the Upper Wakarusa River Watershed, which is located south of Topeka, Kansas, produced twelve specific land cover classes. The watershed boundaries were digitized, and the extraction of land cover types from the data was limited to only those classes which fell within the defined watershed polygon. An acreage assessment of all classes was computed for use by resource management officials in the Upper Wakarusa River Watershed area.

AgRISTARS

PLATE 3

LAND COVER INFORMATION SYSTEMS

CHANGE DETECTION

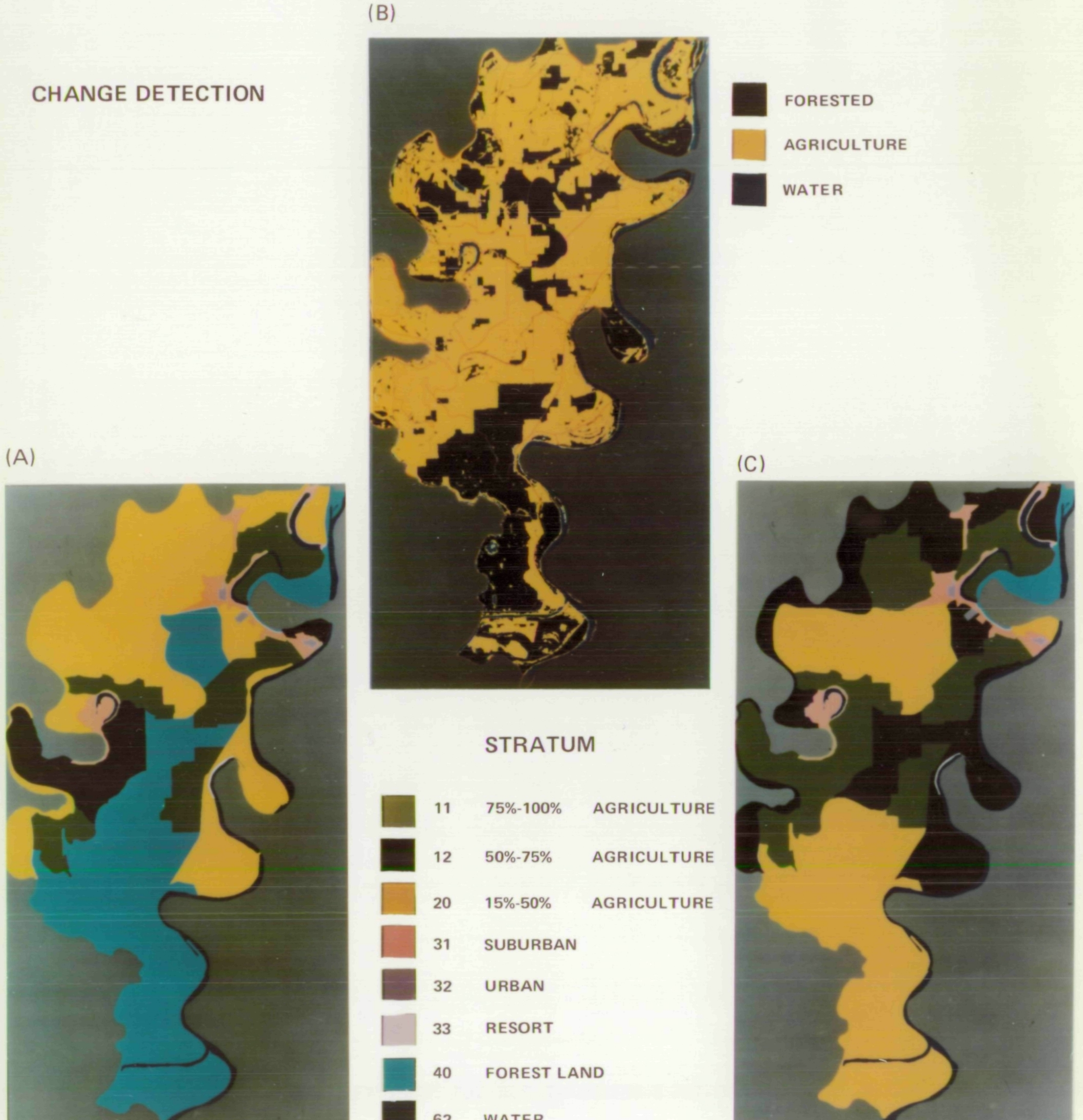
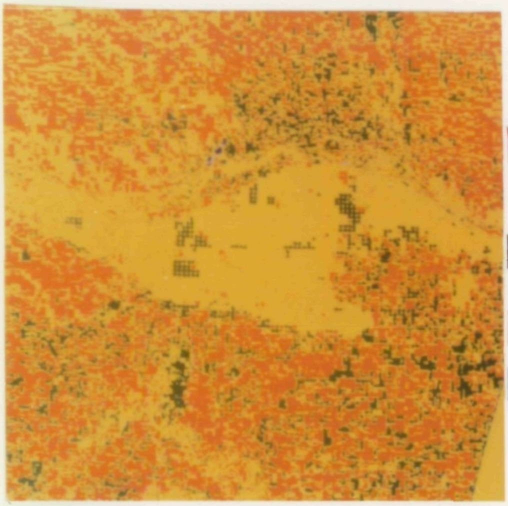


Figure (C) Shows How Landsat MSS Derived Land Uses Within USDA/SRS Polygonal Ground Reference Data (B) were Used to Update the Land Use Intensities of the Area Sampling Frame (A) for Concordia Parish, Louisiana

PLATE 4

AgRISTARS

LAND COVER INFORMATION SYSTEMS ENVIRONMENTAL CHANGE MONITORING



*BARE SOILS/ FALLOW FIELDS

*CROPPED FIELDS

RANGELAND

WATER

*AGRICULTURAL LAND

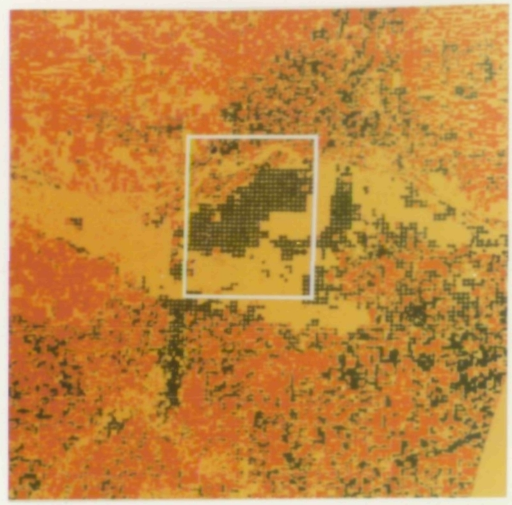
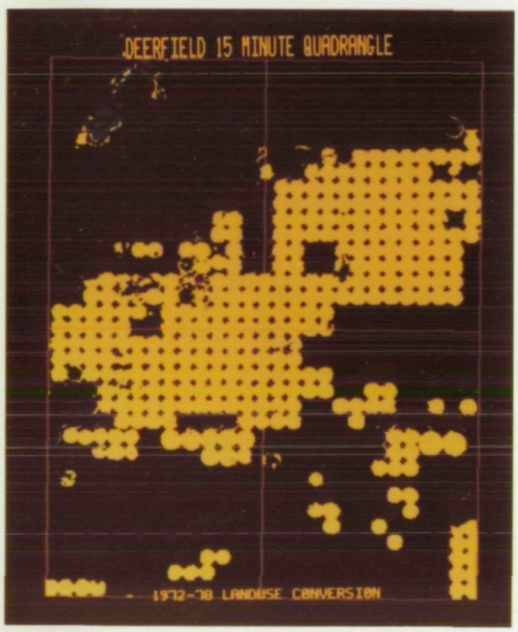


Figure 1 AUGUST 1972

Figure 2 AUGUST 1978

SEQUENTIAL VIEWING OF LAND USE DISTRIBUTIONS ALONG THE ARKANSAS RIVER IN SOUTHWEST KANSAS – APPROXIMATELY A 7° X 7° AREA.

DIFFERENCE BETWEEN 1972 AND 1978 FOR A 15' SUBSET OF THE AREA IN FIGURE 2. AREA OF CHANGE IS QUANTIFIED IN FIGURE 3.



RANGELAND TO AGRICULTURE

WATER TO AGRICULTURE

TABLE 1. QUANTIFICATION OF CHANGE TYPES FOR DEERFIELD 15 AREA

SPECIFIC GEOGRAPHIC AREAL UNIT	TYPE OF LAND USE CHANGE	(Δ/UNIT) %	ACRES	Mi^2
DEERFIELD NW 7.5' QUAD	RANGELAND TO AGRICULTURE WATER TO AGRICULTURE	20.8 1.6	7842 604	12.3 0.9
DEERFIELD NE 7.7' QUAD	RANGELAND TO AGRICULTURE	44.7	16848	26.3
DEERFIELD SW 7.5' QUAD	RANGELAND TO AGRICULTURE	34.3	12963	20.3
DEERFIELD SE 7.5' QUAD	RANGELAND TO AGRICULTURE	20.1	7624	11.9
DEERFIELD 15' QUAD (TOTALS)	RANGELAND TO AGRICULTURE WATER TO AGRICULTURE	30 1.6	45278 604	70.8 0.9

ENVIRONMENTAL CHANGE MONITORING

Illustration of how land cover change data may be presented – either as spatial distributions on a map or as tabular statistics.

AgRISTARS

PLATE 5

MAP PRODUCTS

This computer-implemented land cover classification of Sedgwick County, Kansas, was produced from Landsat MSS data. The large circular area in the right center of the picture is the city of Wichita. Plainly visible are two major interstate highways (yellow, running north to south and east to west), airports (yellow), agricultural fields (red and green), rivers, and forest land (green). The black areas near the right edge of the image are clouds and shadows. A total of 53 spectral signatures was used to produce this product which is geographically referenced to the universal transverse Mercator map projection.

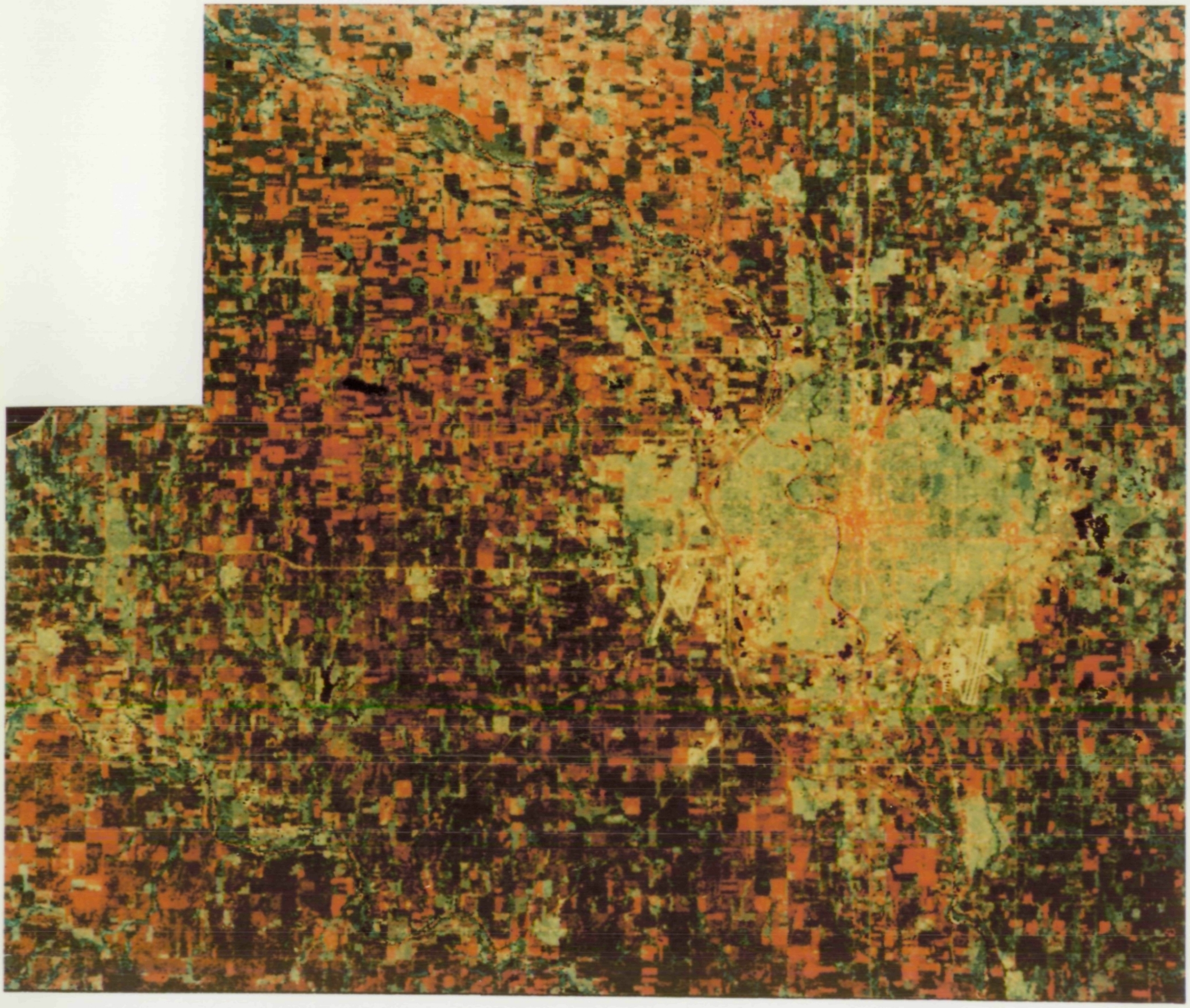
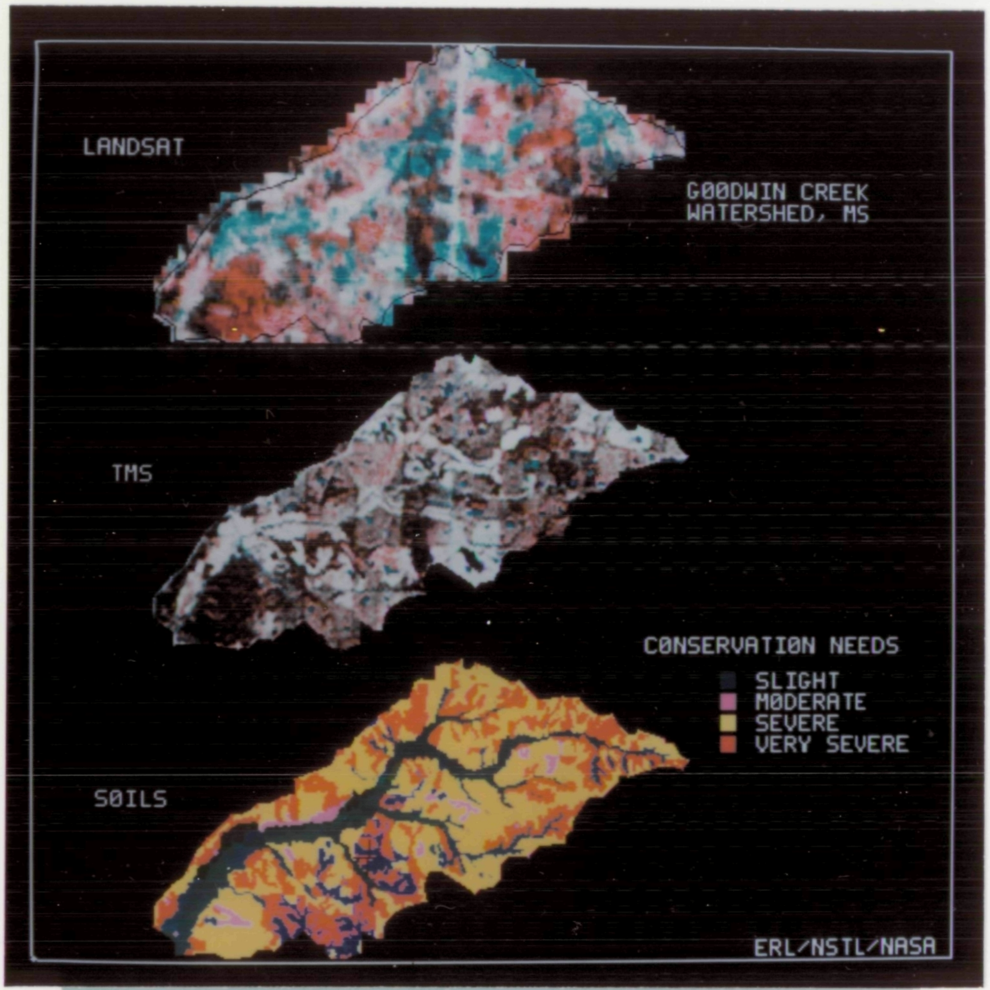
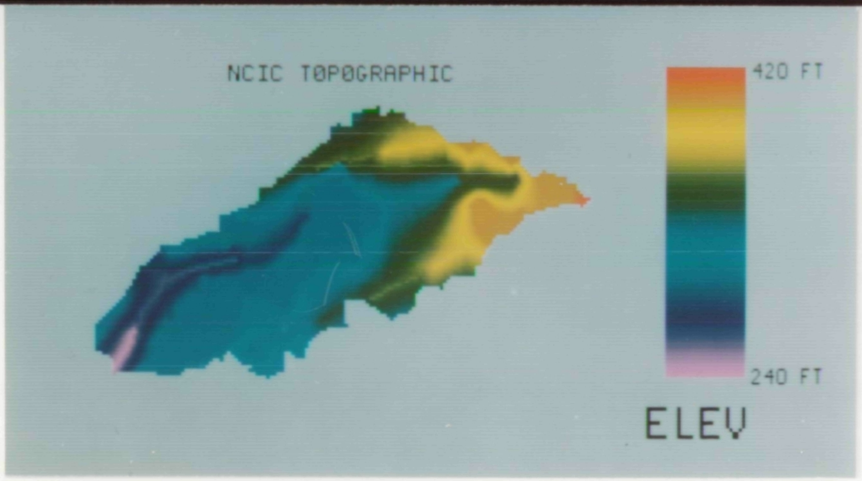


PLATE 6

AgRISTARS

CONSERVATION INVENTORY



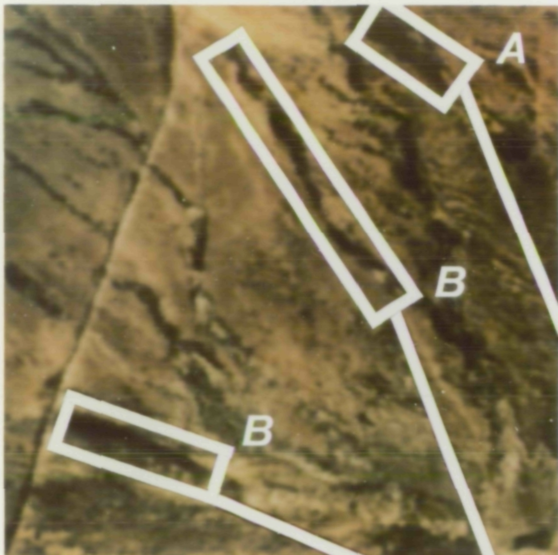


Landsat Scene 21236-1532 was acquired June 11, 1978. Aircraft Scanner Data were acquired November 4, 1980. Digitized soil survey data show areas with erosion hazards.

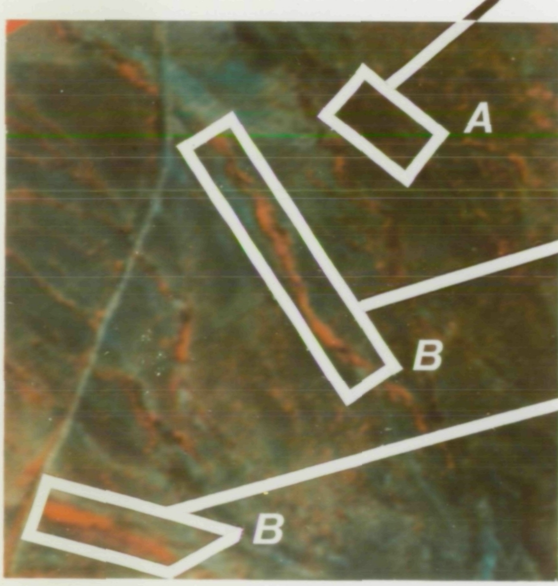
APPLIED RESEARCH AND DATA ANALYSIS

PLATE 7

TECHNIQUES FOR MONITORING SEMI-ARID RANGELAND DEGRADATION WITH REMOTELY SENSED DATA



TMS false color composite, with Band 2 as blue, Band 3 as green, and Band 4 as red. Dormant grassland with a sparse overstory (20% cover) of green shrubs cannot be distinguished from shrub-free grassland.

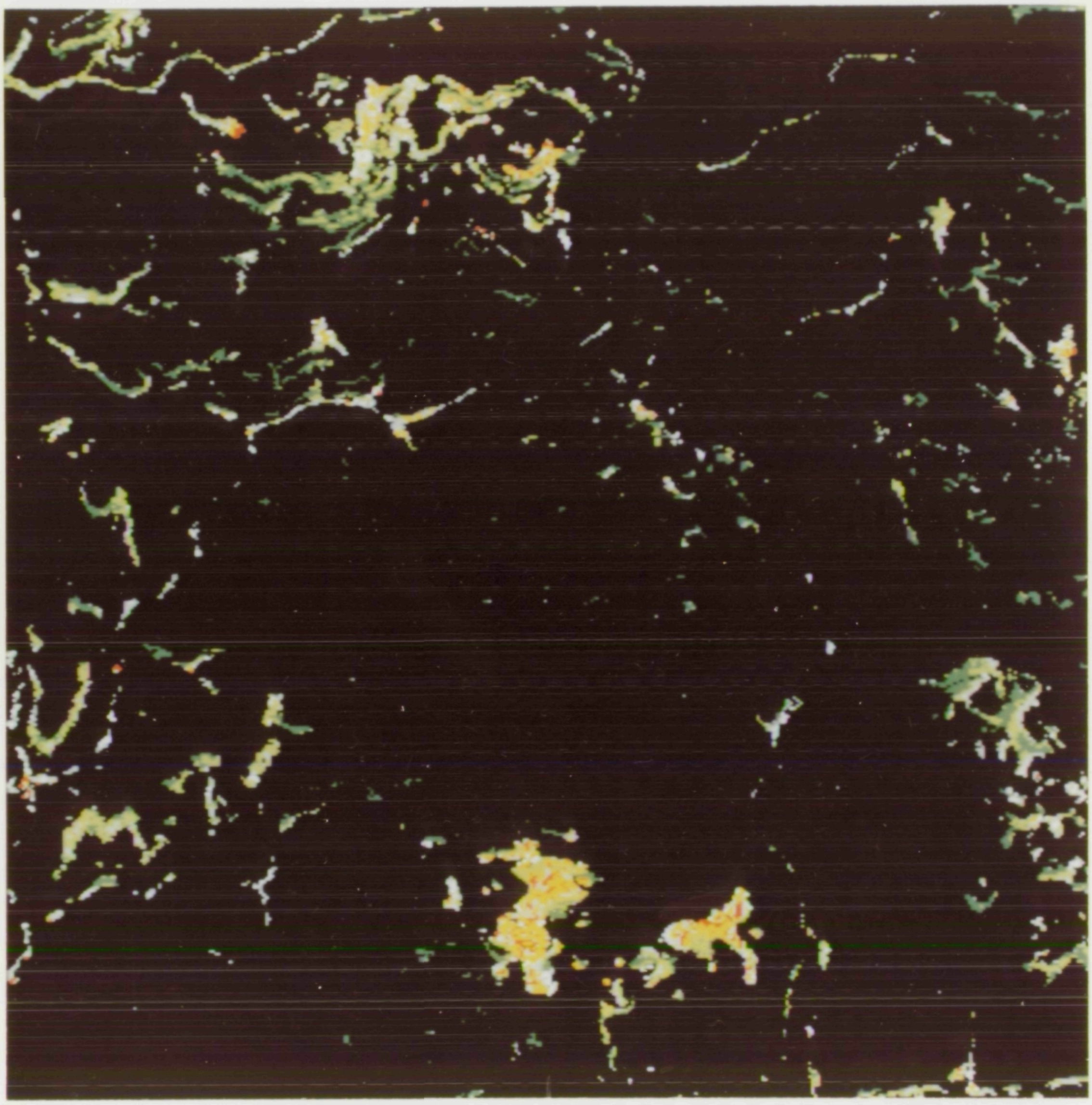


TMS false color composite with Band 2 as blue, Band 3 as green and inverted Band 6 (thermal) as red. For clarity, resolution of the thermal data has been retained at 30 m, the same as in the other bands. The cooling effect of the shrub cover permits identification of shrubby grasslands even when shrub cover is sparse.

APPLIED RESEARCH AND DATA ANALYSIS

PLATE 8

DISCRIMINATION OF SURFACE MINES AS SMALL HETEROGENEOUS FEATURES FROM REMOTELY SENSED DATA

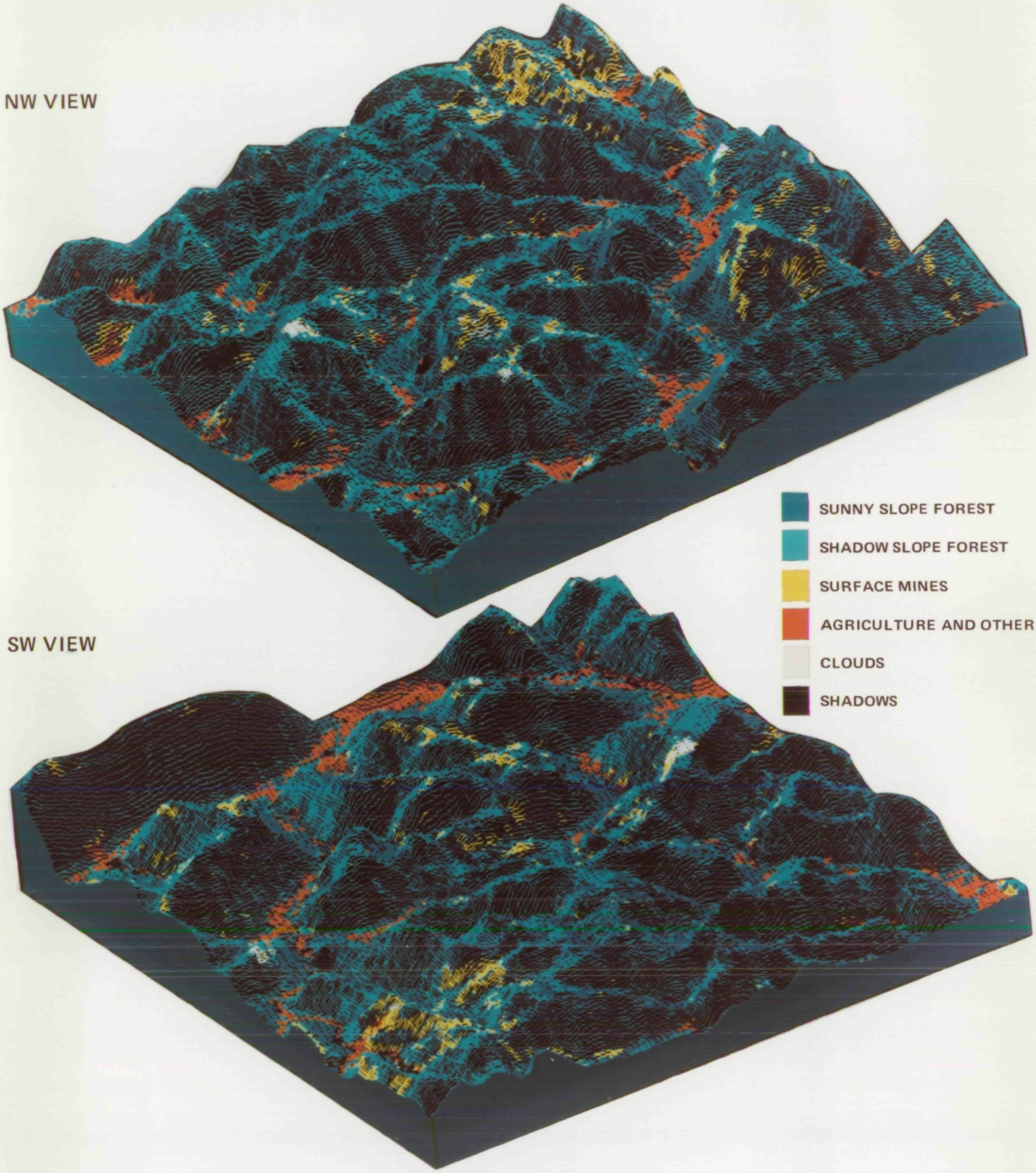


REVEGETATED MINES
ACTIVE MINES
BARE SOIL/ SPOIL
PARTIALLY REVEGETATED MINES
EXPOSED COAL
TRANSISTION LANDS

A thematic mask of lands mined for surface coal was produced by delineating mines from a ratio of first and second principal components derived from TMS data. The discrete range of values corresponding to surface mines in this ratio was then classified on a pixel-by-pixel basis. The result of this procedure yields a classification of surface mines with all other non-related land covers masked out.

APPLIED RESEARCH AND DATA ANALYSIS

PLATE 9



1979 LANDSAT CLASSIFICATION OF SURFACE MINES AROUND PINEVILLE, KENTUCKY, TOPO QUAD.
3-D PERSPECTIVE

These scenes of Landsat MSS classification, derived for the Pineville 1:24,000 scale topographic quadrangle in southeastern Kentucky, illustrate how the inclusion of a third dimension significantly increases one's perception of remotely sensed data products. A three-dimensional effect was applied to the original classification of surface mines (in yellow) produced from digital MSS data. Consequently, the visual effect of the data has been enhanced which greatly assists the interpretation of surface mines as a function of elevation, aspect, and slope in addition to spectral response.

PLATE 10

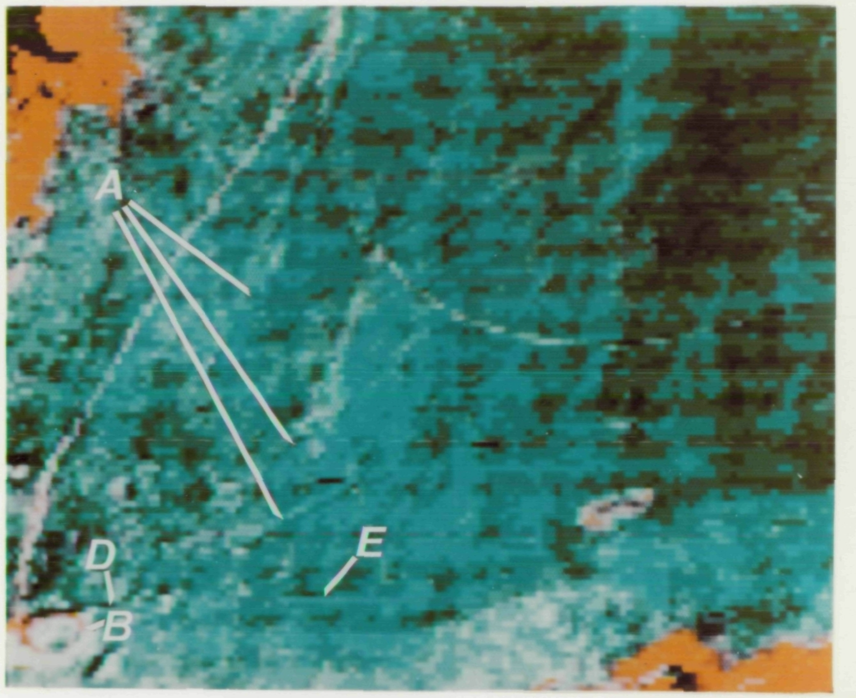
APPLIED RESEARCH AND DATA ANALYSIS

ARCHEOLOGICAL INVESTIGATION

In cooperation with the National Park Service, ERL has been investigating the feasibility of detecting archeological phenomena with remotely sensed scanner data. Preliminary results from the Thematic Mapper Simulator (TMS) and the Thermal Infrared Multispectral Scanner (TIMS) data, shown here, illustrate the potential for conducting archeological inventories with advanced technology. These studies will be continued in FY1983 and expanded to include synthetic aperture radar data. The field photographs below show the phenomena from ground level which are correlated with the imagery

TMS DAY

Thematic Mapper Simulator data acquired over Chaco Canyon in April, 1982 at 10 meters resolution. This false color composite of TMS Bands 4 (0.76-0.90 μm) and 7 (2.08-235 μm) reveals prehistoric Chacoan roadways and other archeological features. Variations in blue and green reveal subtle vegetative differences in an arid environment.



TMS Data Acquired in the Daytime

A_1 Map Showing Prehistorical Roadways

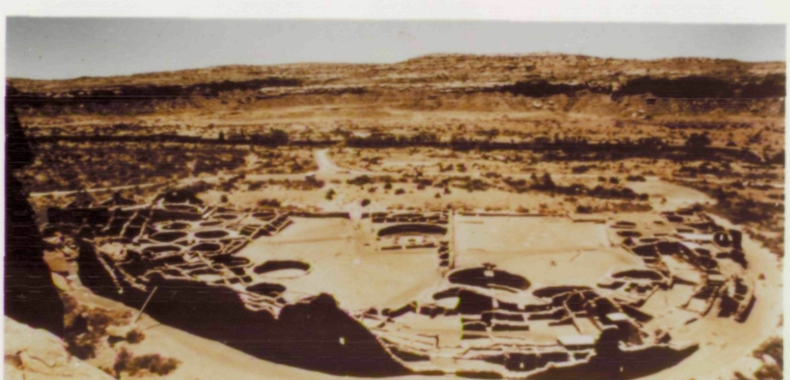
A. Prehistoric Roads

The ground photo below was taken looking north from an entrance gate at Pueblo Alto (located on the adjacent map with red box). Major Chacoan roads converge at this point although the phenomenon is invisible from ground level. Analysis of the roadway system may render socio-cultural understanding of Anasazi society.

A_2

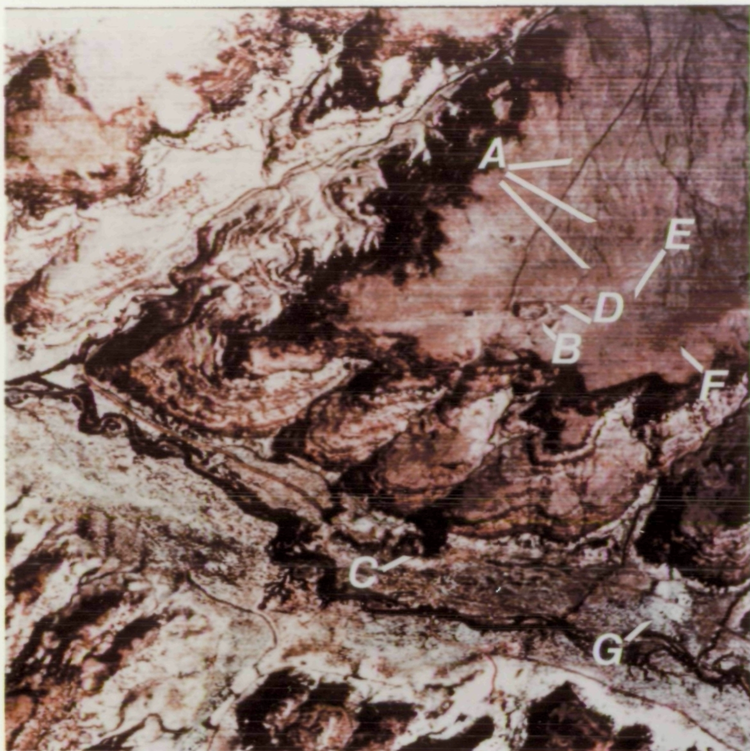
B. Excavated Site (Pueblo Alto)

C. Excavated Site (Pueblo Bonito)



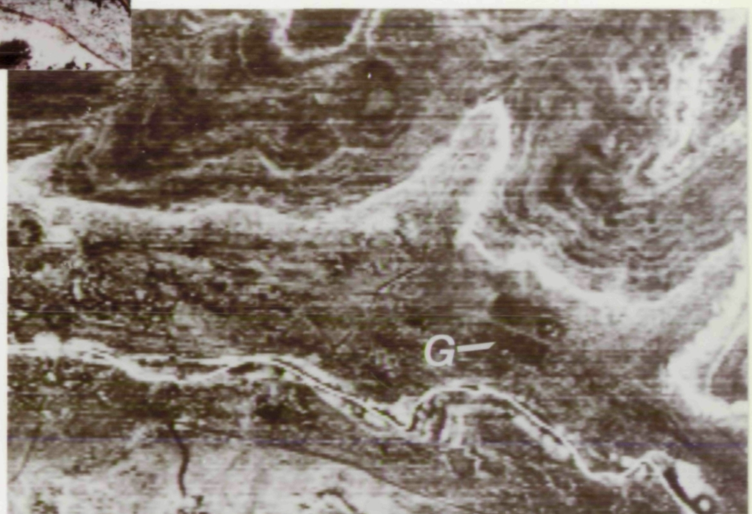
TIMS NIGHT

Thermal Infrared Multispectral Scanner data band 3 (9.0-9.4 μm) acquired during the day and at night over Chaco Canyon in August 1982 at 5 meter resolution. The imagery reveals prehistoric Anasazi roadways, subterranean walls, and both excavated and unexcavated archeological sites. Although invisible to the human eye, the prehistoric roadways are clearly observable in the image because of the inherent thermal inertia differences exhibited. Also notice the difference in delineating the prehistoric agricultural field in the data acquired at solar noon and at night. In the night data, the actual parameter of the field is well defined.



TIMS Data Acquired in the Daytime

TIMS Data Acquired at Nighttime



D. Excavated Wall at Pueblo Alto

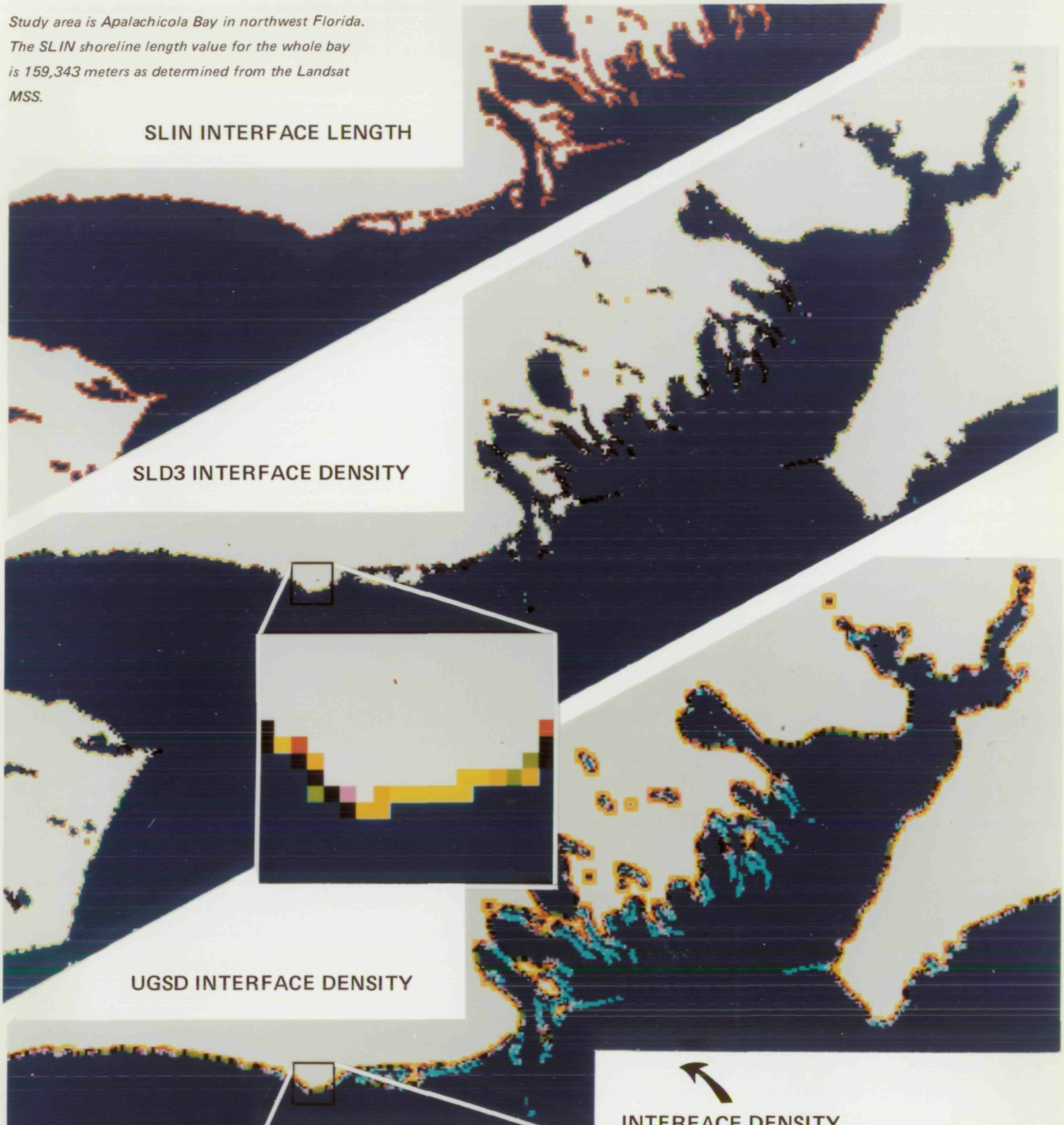
E. Unexcavated Wall at Pueblo Alto

F. Unexcavated Archeological Site

G. Prehistoric Agricultural Field in the Chaco Canyon Bottom

PLATE 11 APPLIED RESEARCH AND DATA ANALYSIS

Study area is Apalachicola Bay in northwest Florida. The SLIN shoreline length value for the whole bay is 159,343 meters as determined from the Landsat MSS.



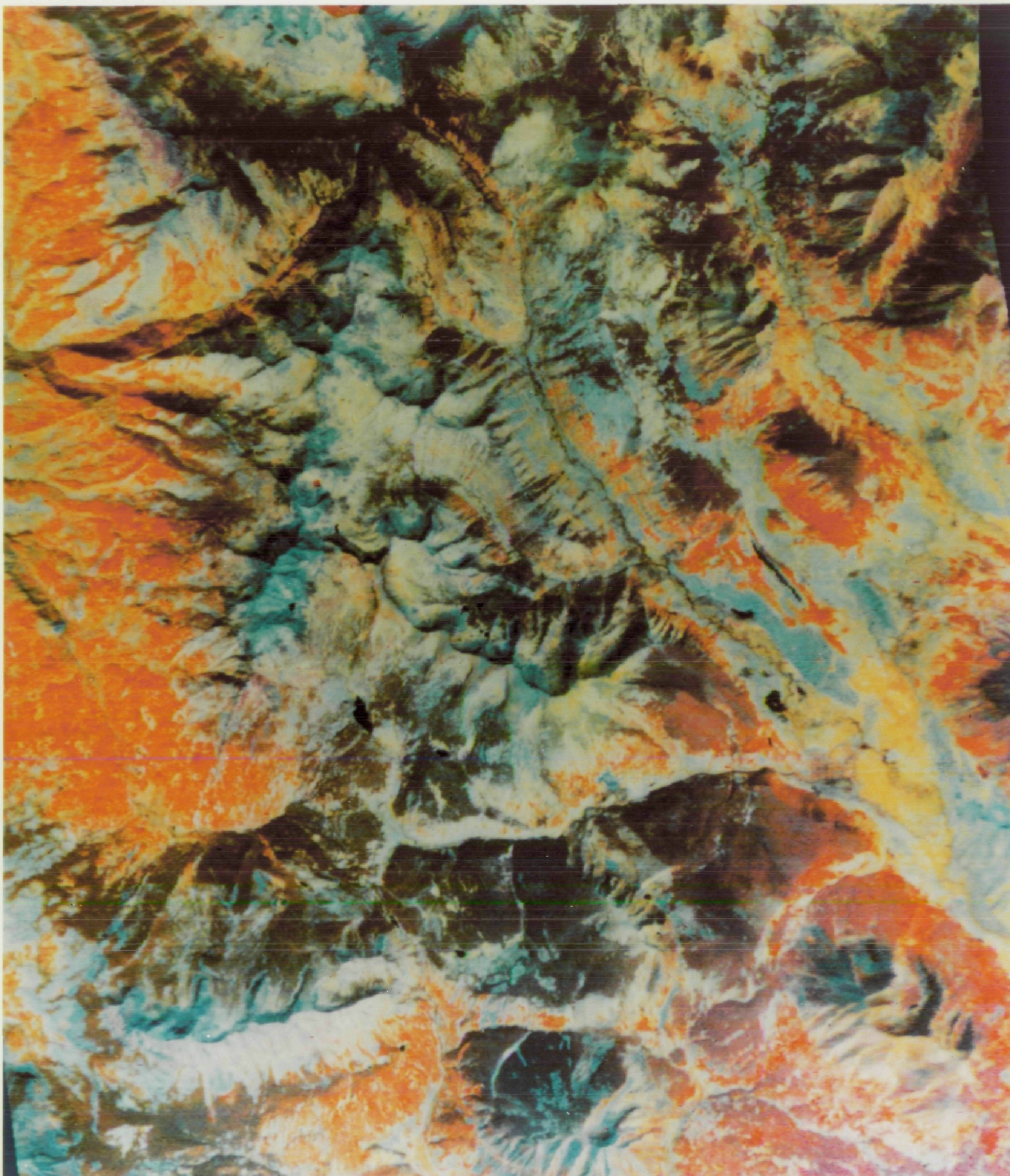
INTERFACE DENSITY
(SHORELINE COMPLEXITY)

The algorithm SLD3 computes interface density for the interface pixels only. The module UGSD computes interface density values for all of the pixels in a 5x5 window which was stepped through the SLIN data.

APPLIED RESEARCH AND DATA ANALYSIS

GEOLOGICAL MAPPING PROJECT

PLATE 12

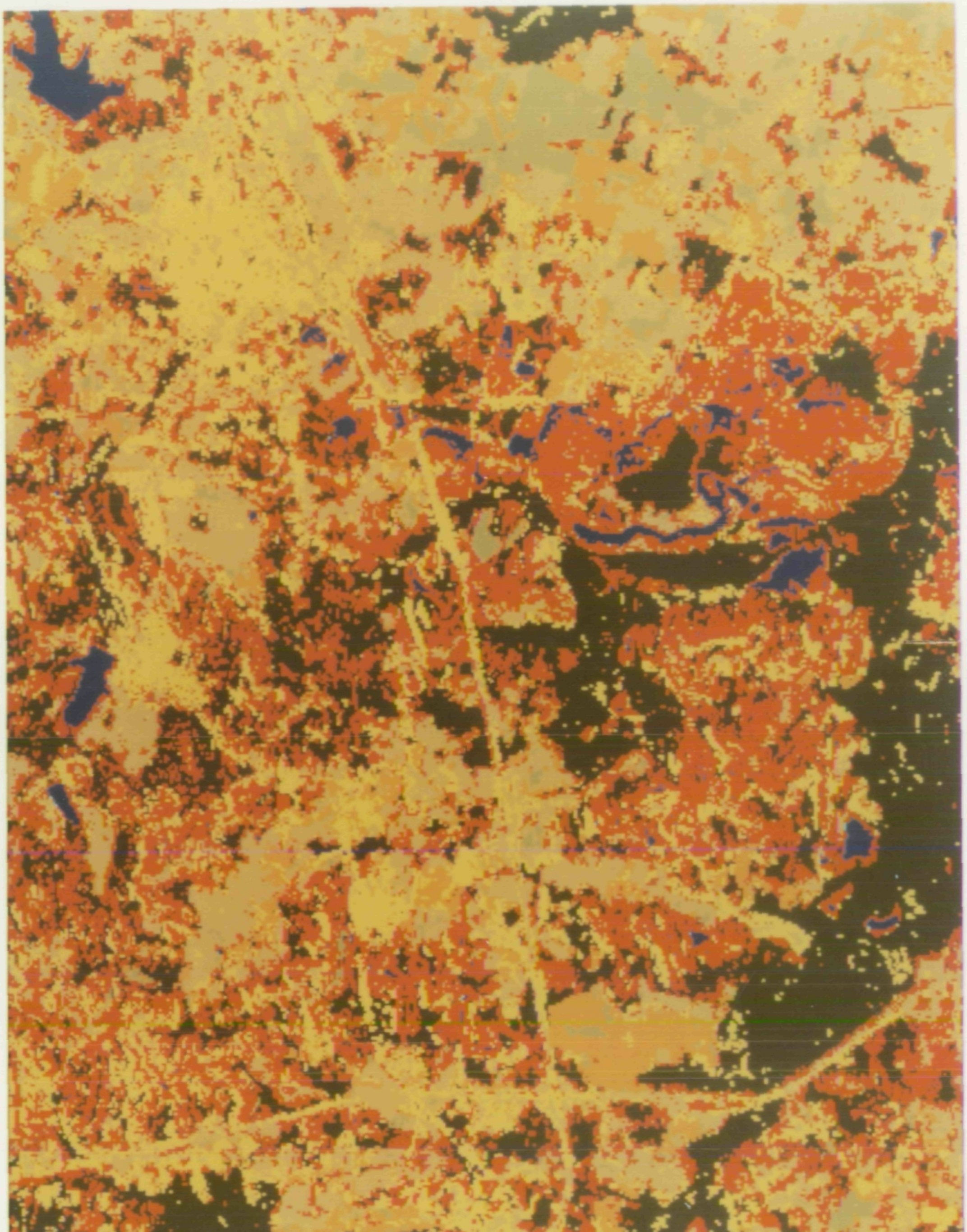


COLOR COMPOSITE OF "DECORRELATED" DATA OF MT. EMMONS, COLORADO

TM bands are usually correlated, thus in making a color composite, as one band becomes brighter, others also tend to become brighter. If they are highly correlated, the color image becomes a near monochrome. This image which shows Band 6 as blue, Band 5 as green, and Band 4 as red was generated by decorrelating the data, thereby stretching the data. The image depicts most of the rock and vegetation types shown in published maps.

PLATE 13 **APPLIED RESEARCH AND DATA ANALYSIS**

MICROWAVE SENSOR ANALYSIS



WESTERN KENTUCKY COAL REGION - SAR X AND L BANDS AND MSS BANDS 5 AND 7 CLASSIFICATION

PASTURE
FOREST
RESIDENTIAL
SOYBEAN FIELD
CORN FIELD
WATER
STRIP MINE

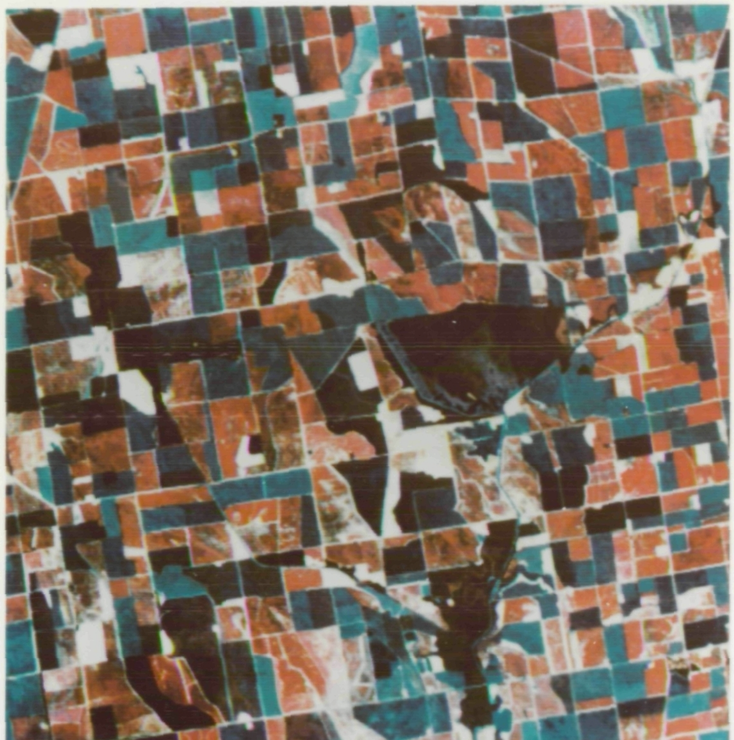
The classification of the five-band SAR/MSS data set separates the strip mine from residential, forest, and agricultural classes. The delineation of soybean fields from corn fields is distinctive.

JOINT RESEARCH PROJECTS

PLATE 14

CROP MENSURATION AND MAPPING

POINSETT CO. ARKANSAS TM DATA

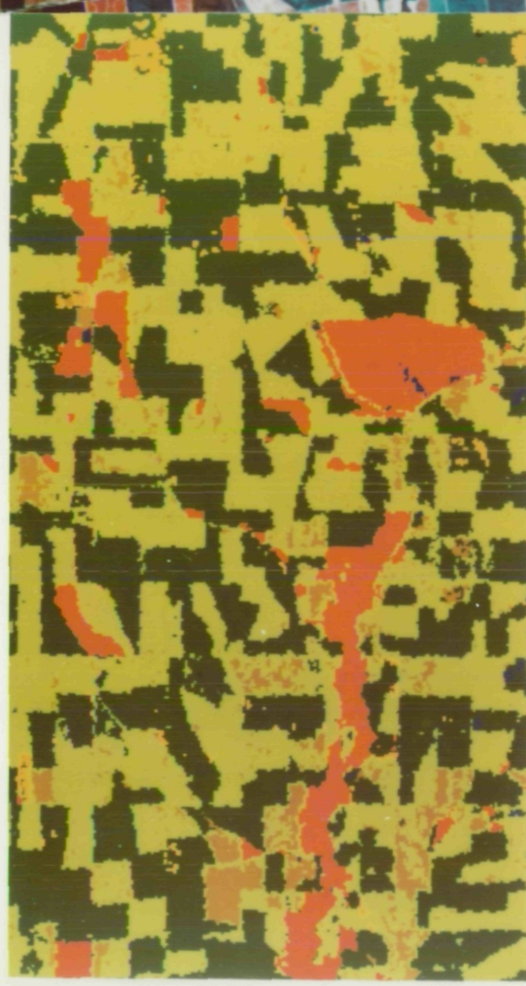


Fifty-two polygons were identified and used to name and group the 30 spectral classes into six land cover categories.

1. *Hardwood*
2. *Fallow*
3. *Rice*
4. *Soybeans*
5. *Winter wheat/soybeans*
6. *Water*

Overall accuracy of the land cover classifications was 97%. The highest percent accuracies for classes were recorded for hardwood, rice, and soybeans with percentages of 100, 99, and 95, respectively.

MSS DATA



The same polygons and land cover categories that were used for the TM data classification were used for the MSS data classification.

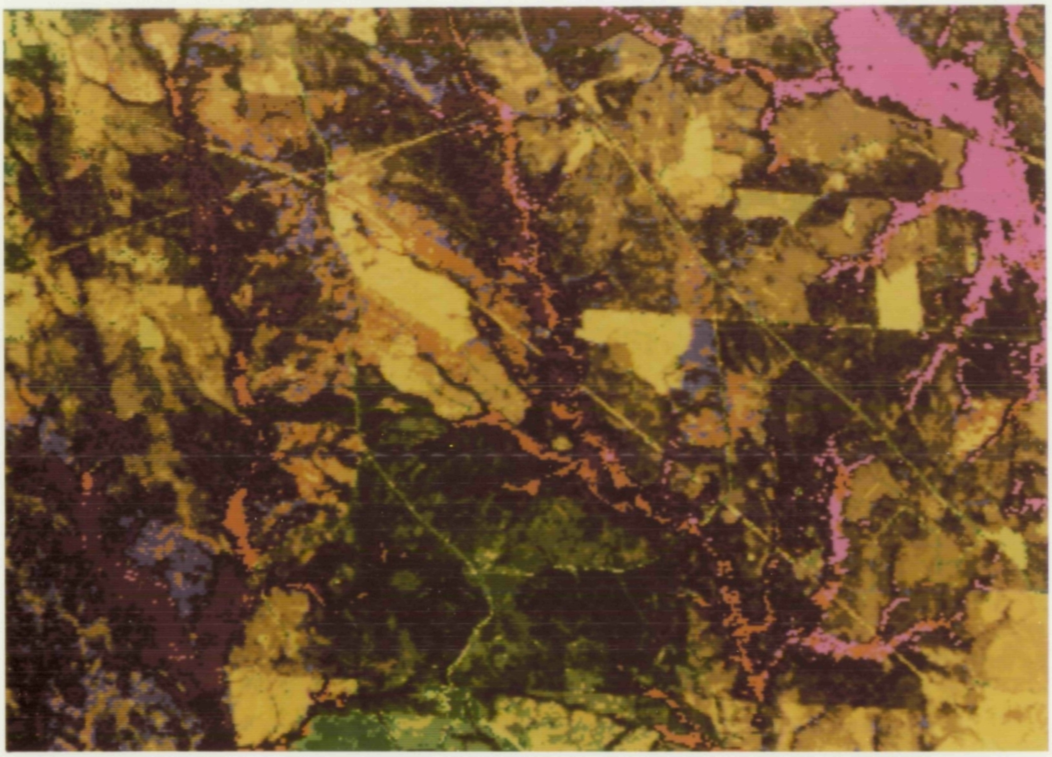
The three classes which had the most accurate classifications were hardwood, 100%; rice, 99%; and soybeans, 90%.

PLATE 15

JOINT RESEARCH PROJECTS

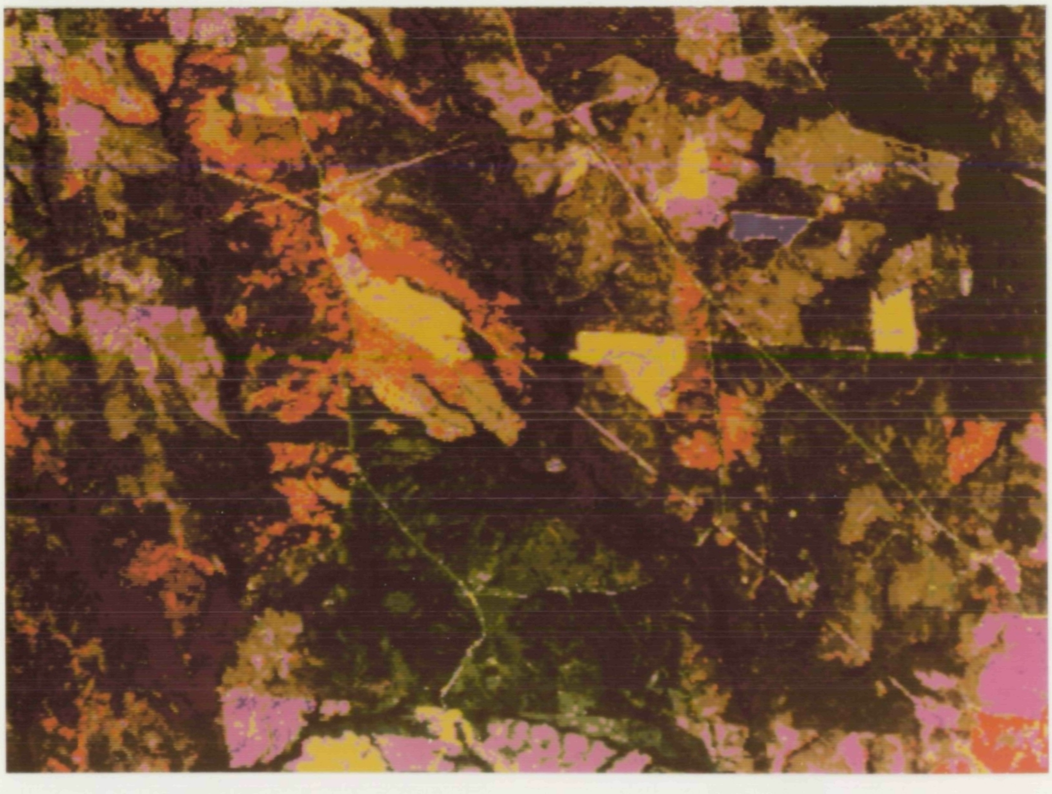
TIMBER RESOURCES AND INVENTORY

- LOBLOLLY PINE STANDS
- ATLANTIC WHITE CEDAR/HARDWOOD



SPECIES IDENTIFICATION AS DEPICTED BY TMS 7 BAND CLASSIFICATION

- YOUNG REGENERATION
- SITE PREPARATION
- SITE PREPARATION (DOUBLE DISKED)
- BURNED STANDS



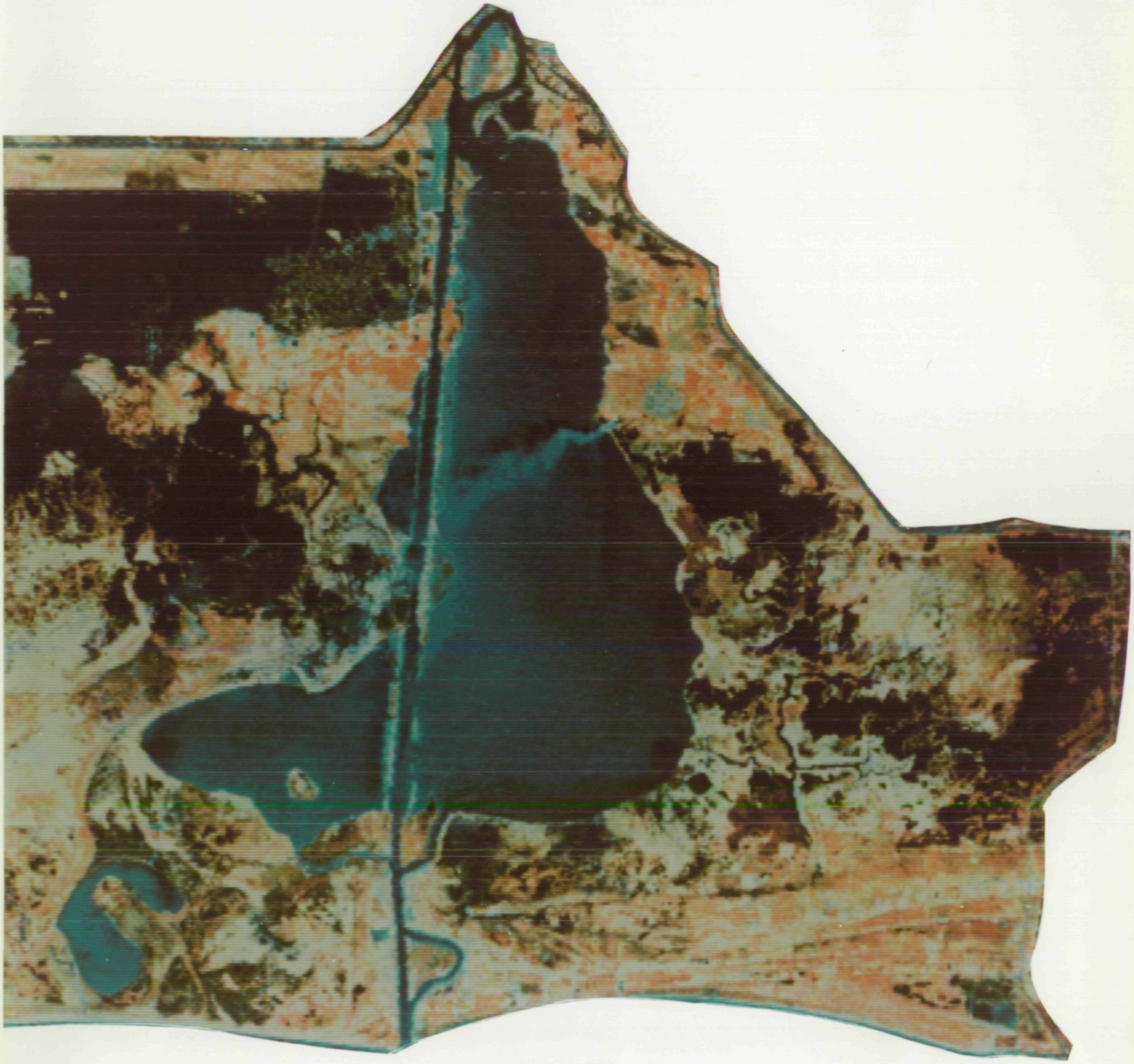
SILVICULTURE ACTIVITY AS DEPICTED BY TMS 7 BAND CLASSIFICATION

TMS Data Acquired Over Baldwin County, Alabama, in Support of Cooperative Programs with International Paper Co.

JOINT RESEARCH PROJECTS

<u>PLATE 16</u>

WETLANDS PRODUCTIVE CAPACITY MODELING JOINT RESEARCH PROJECT



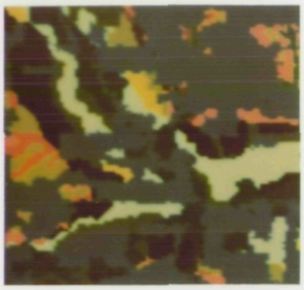
CALCASIEU LAKE BASIN LANDSAT MSS DATA...

The Landsat band-composite image represents the study area selected for the joint NASA and NMFS research project. Colors were selected to simulate color IR photography.

PLATE 17

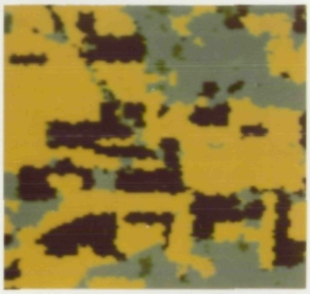
JOINT RESEARCH PROJECTS

FIRST (FARMER'S INFORMATION AND RESOURCE SYSTEM TECHNOLOGY) WITH MFA, INC.



Increasingly darker shades of green indicate soybean fields on soils with higher yield potential, while red shades denote lower yielding soils.

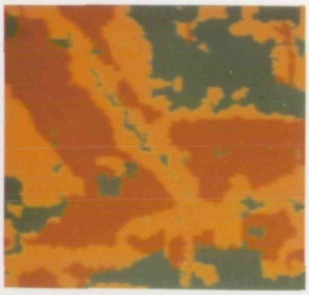
SOYBEAN YIELD POTENTIAL



Expected fertilizer needs derived from regional sales records are summarized by crop, with darker shades of green indicating higher N requirements.

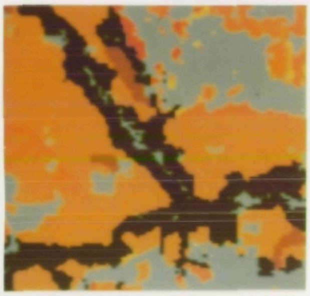
NITROGEN FERTILIZER

DARLINGTON, MISSOURI QUADRANGLES



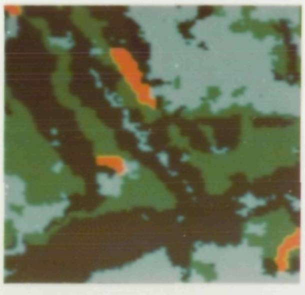
Herbicide effectiveness requires higher (brown) or lower (orange) rates for adequate weed control depending on soil organic matter levels.

WEED CONTROL IN VARIABLE SOILS



Cultivated fields well-suited for irrigation (green) do not possess restrictive slope, aeration, or available water content of other, less suitable fields (shades of brown).

CULTIVATED FIELDS



Fields with high contents of expanding clays (red) are slow-drying and present trafficability problems that are critical for spring planting decisions.

TRAFFICABILITY FOR ROW CROPS

LAND LOSS ASSESSMENT

In order to focus NASA Regional Application Project Efforts at the sub-state level of government, NASA/NSTL/ERL, Louisiana State University, and Lafourche Parish, Louisiana, collaborated in the Louisiana Sub-state Application Project. Lafourche Parish and her sister parishes, located in Louisiana's Deltic Plains, are experiencing rapid losses of land due to marsh deterioration and beach erosion. Historically, these parishes have lacked the informational base to counter environmental degradation. Through this project, Lafourche Parish, for the first time, obtained synoptic and site-specific land cover baselines. Using temporal analysis, they were able to monitor land cover change and locate areas of land loss.

LAND LOSS BY SOIL TYPE IN LAFOURCHE PARISH

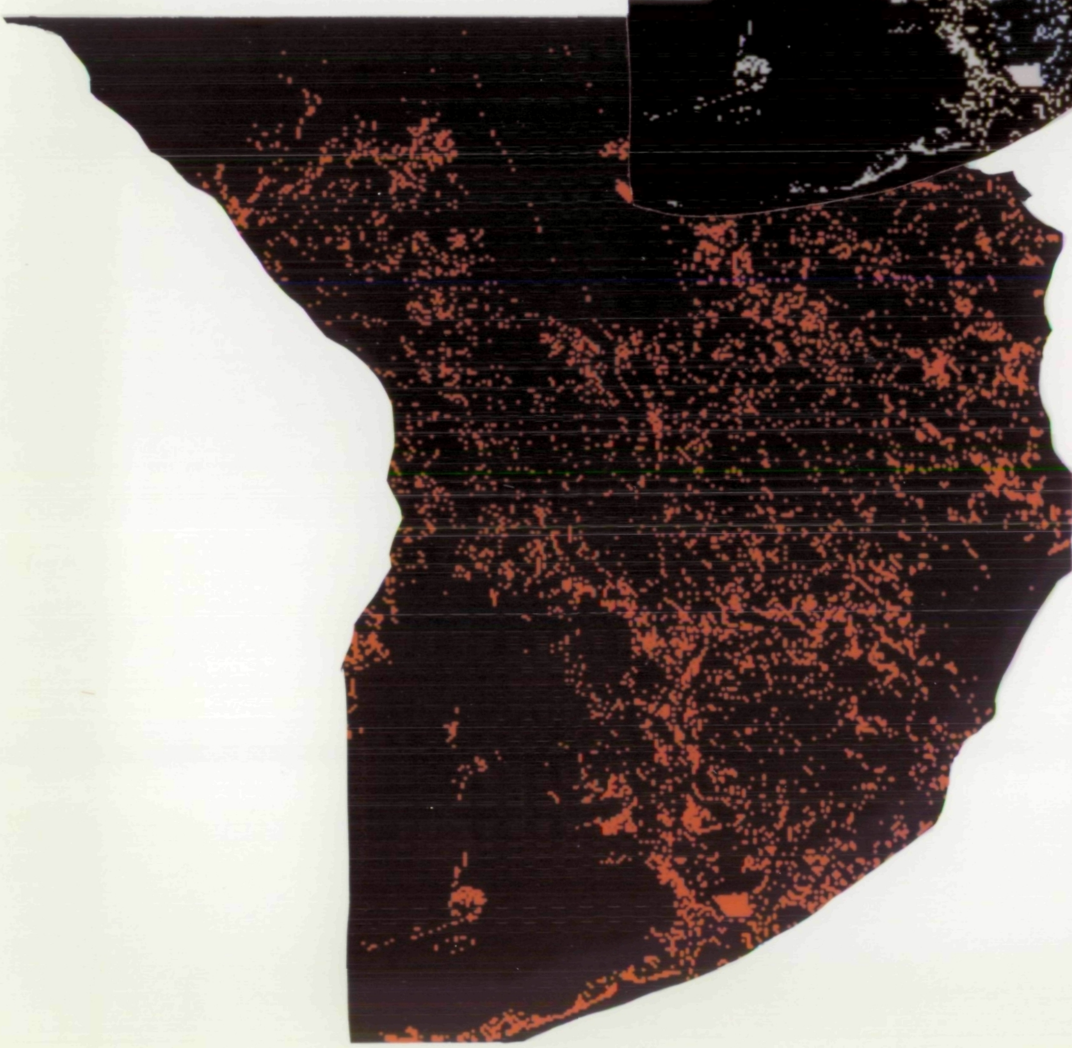
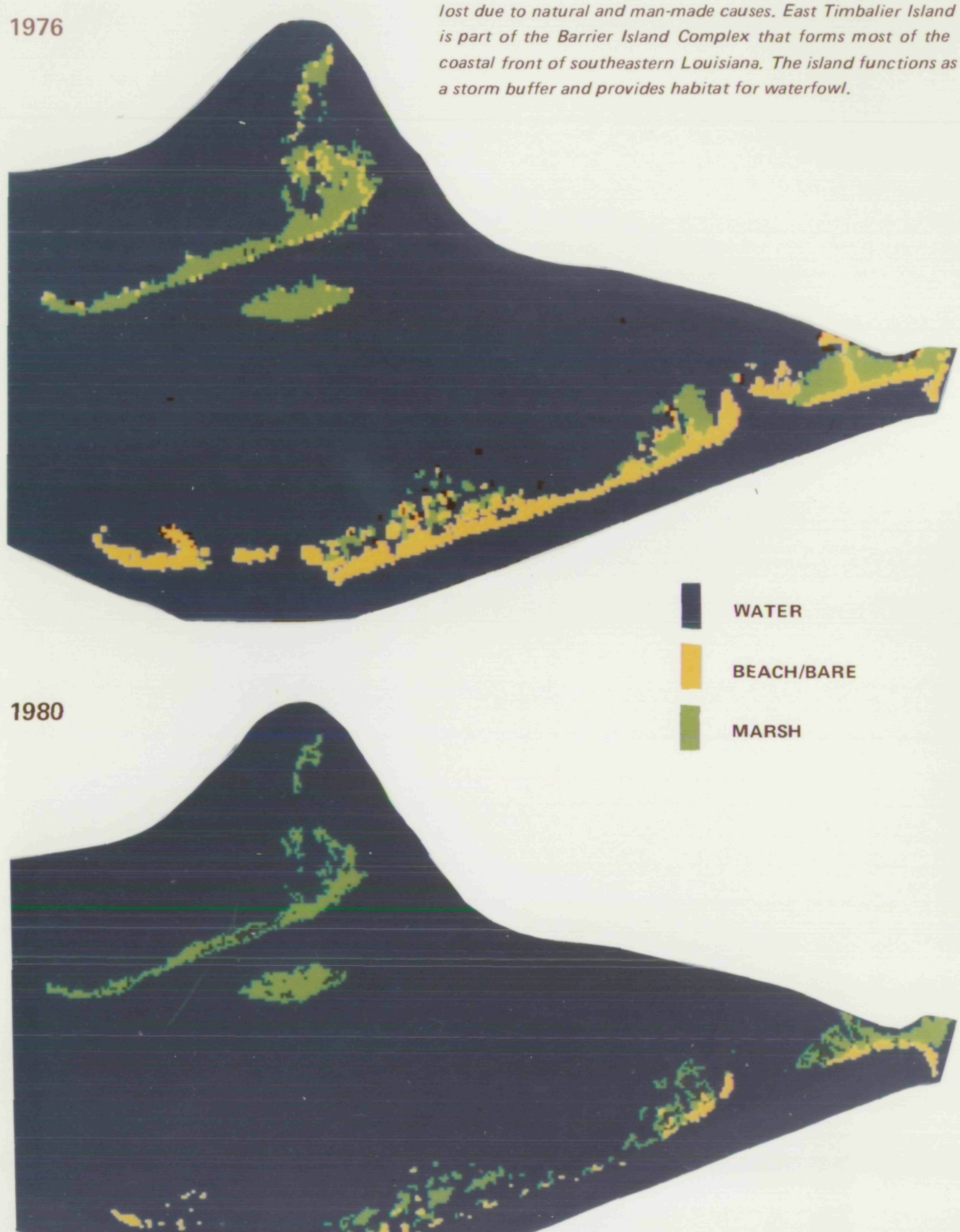


PLATE 19

TEST AND EVALUATION

LAFOURCHE PARISH TIMBALIER ENVIRONMENTAL MANAGEMENT UNIT

The Timbalier E.M.U. is one of 17 E.M.U.'s within Lafourche Parish analyzed to determine the amount and type of land being lost due to natural and man-made causes. East Timbalier Island is part of the Barrier Island Complex that forms most of the coastal front of southeastern Louisiana. The island functions as a storm buffer and provides habitat for waterfowl.



- **APPLIED RESEARCH AND DATA ANALYSIS**
  - **Monitoring of Rangeland Degradation**
  - **Discrimination of Small Mine Features**
  - **Soil Delineation Research**
  - **Archaeological Investigation**
  - **Fundamental Research: Scene-to-Map Registration**
  - **Interface Measuration Techniques**
    - **Interface Length**
    - **Interface Density**
  - **Non-Renewable Resources Studies**
    - **Geological Mapping**
    - **Geobotanical Applications**
  - **Microwave Sensor Analysis**

APPLIED RESEARCH and DATA ANALYSIS

Page Intentionally Left Blank

MONITORING OF RANGELAND DEGRADATION

The productive capacity of millions of acres of arid and semi-arid rangeland is lost each year to the combined effects of overgrazing, drought, and soil erosion. Spacecraft-acquired data have great potential for monitoring arid rangelands because they can provide repetitive synoptic coverage of large areas. For this potential to be fully realized, improved techniques are needed for extracting information from spectral data and relating spectral signature changes to long term trends. Predictive models can be generated from such information. Task No. 1 of the Land Resources Applied Research RTOP, "Techniques for Monitoring Semi-Arid Rangeland Degradation with Remotely Sensed Data," is to develop techniques to maximize the contribution of remote sensing to the assessment, monitoring, and prediction of semi-arid rangeland degradation.

Multispectral classification of Landsat MSS data has been used to monitor rangeland vegetation, but MSS spectral classes are often only weakly correlated with vegetation type in arid regions where vegetative cover is sparse. To determine the potential utility of Thematic Mapper data in improving discrimination of vegetation types, data from the NSTL/ERL Thematic Mapper Simulator and from Landsat MSS were acquired for the Jornada test site in southern New Mexico. Unsupervised signature development and maximum-likelihood classification were performed using existing ELAS software, and classification accuracy was determined for the same ground truth areas used to assign spectral classes to vegetation types.

While the resulting accuracy percentages are higher than would be obtained if an independent set of ground truth areas had been used for accuracy assessment, they do permit comparisons of classification performance. Classification accuracy was higher for TMS data than for MSS data, regardless of whether the non-thermal TMS bands were at 30m or 80m resolution and whether the thermal band was included or not. The highest accuracy obtained with TMS data was about 10% greater than MSS accuracy. (See table 7.)

Analysis of the TMS data also indicated that Thematic Mapper thermal data might prove to be useful in monitoring green biomass in arid regions. Green vegetation indexes based on the high near IR/red reflectivity of green leaves can be calculated from MSS data. Although these indexes have been used successfully to measure rangeland productivity under certain circumstances, they are unreliable in arid regions where green vegetation is sparse.

TABLE 7

TMS AND MSS CLASSIFICATION PERFORMANCE ON CLASS-NAMING FIELDS

DATA	ACCURACY %
MSS	64.9
TMS	
80m Bands 1-5, 7	84.4
80m Bands 1-7	77.7
30m Bands 1-5, 7	75.2
30m Bands 1-7	77.5

When TMS spectral signatures of different ground truth areas were compared, it was observed that areas with green vegetation were cooler than areas of dead vegetation or bare soil having the same albedo, presumably because of the strong cooling effect of transpiration under conditions of high solar irradiance and low humidity. Under the appropriate conditions, this cooling effect is far more sensitive to small amounts of green biomass than the near IR/red ratio. (See plate plate 7.)

The details of these investigations are published in a report entitled "Analysis of Dry Season Thematic Mapper Simulator and Landsat Multispectral Scanner Data for Jornada Test Site" (NSTL/ERL No. 211). In FY1983, the use of Thematic Mapper thermal data for monitoring green biomass will be further developed and tested.

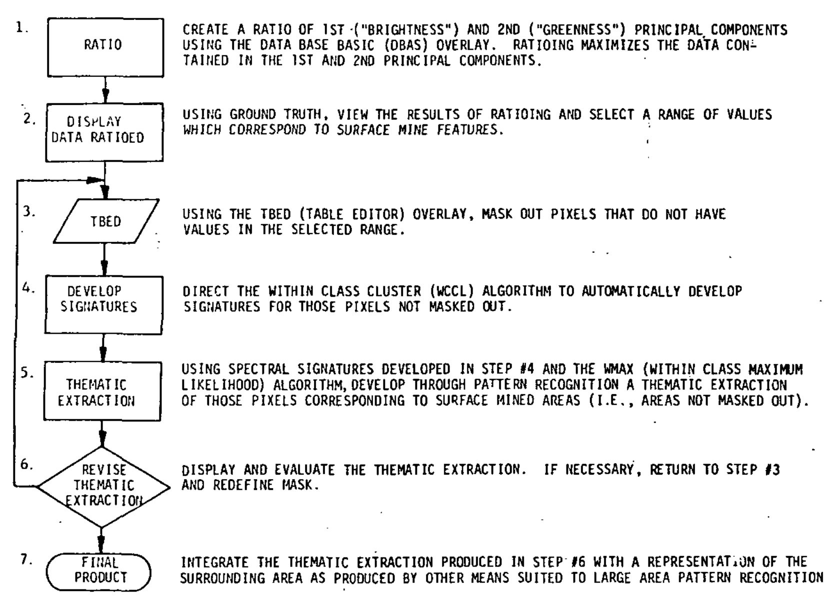
Another aspect of this study is the development of techniques for using remotely sensed data and Geobased Information System analysis to assess wind erosion hazard. Digitized soil maps, which were incorporated into the data base during FY1982, can be used with published tables to obtain the value for erodibility in the wind erosion equation. Methods for deriving vegetative cover factors (to reduce the erodibility) from remotely sensed data are currently being tested and will be used in the wind erosion equation in FY1983.

DISCRIMINATION OF SMALL, HETEROGENEOUS SURFACE MINE FEATURES FROM THEMATIC MAPPER SIMULATOR (TMS) DATA

A technique developed during FY1981 which employs band-ratioing and principal components analysis for the thematic extraction of surface mine features from Landsat data has been extended to TMS data. This technique (figure 2) was used to produce a thematic "mask" of surface mines as small heterogeneous features from TMS data collected in February, 1981, over a portion of the eastern Kentucky coal field. A ratio of the first and second principal components derived from these data was utilized to define spectral response values specifically associated with surface-mined lands.

FIGURE 2

TECHNIQUE FOR SPECTRAL SIGNATURE DEVELOPMENT IN AREAS WITH SMALL, HETEROGENEOUS FEATURES (SURFACE MINES)



Once these values were identified, the WCCL (Within Class Cluster) algorithm in ELAS was used to develop spectral signatures (on a pixel-by-pixel basis) for those areas identified by the mask. The spectral signatures were grouped into 6 classes by using a maximum-likelihood classifier. (Refer to plates 8 and 9.) In comparison with the Landsat MSS, the improved spatial and spectral resolution capabilities of the TMS provide better discrimination of mined lands and discrete spatial entities and permit a more detailed classification of heterogeneous land covers within the mines to be derived. (Refer to ERL Report No. 206, "A Technique for Using Multidate Landsat MSS Data to Discriminate Small, Heterogeneous Surface Mine Features in Eastern Kentucky" by Dale A. Quattrochi, March 1982.)

SOIL DELINEATION RESEARCH

Research was initiated during FY1982 that was designed to explore remote sensing techniques for soil delineation. Controlled ground-based experiments relating soil properties and field conditions to variations in soil spectral response form the basis for future sensor studies aimed at correlating mapped spectral classes of non-vegetated landscapes with soil map unit variability. The ultimate goal is the development of remote sensing techniques capable of delineating soils in a manner which would serve to expedite the preparation of higher-order soil surveys as they are conducted by the National Cooperative Soil Survey. Initial work has focused on soil properties characteristic of the low-base status forest soils (Ulti-soils) typical of the southeastern United States.

Soil landscapes in the highly weathered uplands of the southeastern United States coastal plain are delineated partly on the basis of soil characteristics related to the free iron oxide contents of these soils. Soil reflectance is strongly influenced by iron oxide content and by the organic matter content and texture. Samples from the 4 predominate agricultural soils of this region have been studied with a ground-level multiband radiometer to determine the intrinsic spectral separability of these soils. Subsurface soil reflectances for each of these soil series were also studied because of the tendency for subsoil horizons to be incorporated into the plow layer after removal of the original surface layer by erosion.

The reflectance measurements were taken with a Barnes Model 12-1000 modular multiband radiometer, covering the 6 reflective bands of the Landsat Thematic Mapper in addition to a near IR band from 1.15 to 1.30 μm. (See table 8.) The instrument was calibrated against a barium sulfate reflectance standard with the output ex-

TABLE 8

COMPARISON OF GROUND-BASED RADIOMETER AND THEMATIC MAPPER BANDS

Barnes 12-1000 Spectral Bands		Thematic Mapper Band Designation
0.45-0.52μm	Visible	1
0.52-0.60μm		2
0.63-0.69μm		3
0.76-0.90μm 1.15-1.30μm	Near IR	4
1.55-1.75μm	Middle IR	5
2.08-2.35μm		7
10.40-12.50μm	Thermal IR	6

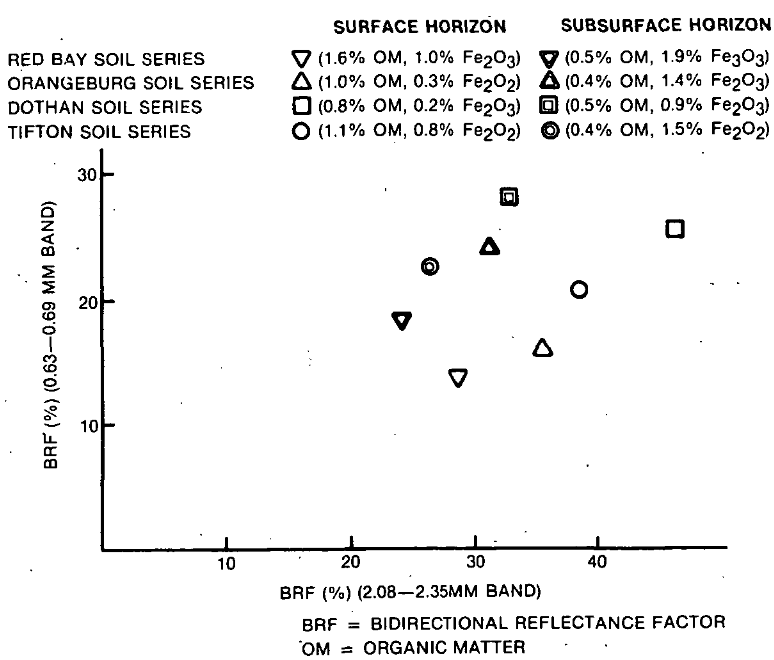
pressed as a percent bidirectional reflectance factor. Although measurements were taken at a range of moisture contents, results were given here for air-dried, uncrusted soils representative of conventionally tilled farmland.

It was found that reflectance in the red band (0.63-0.69 μm) and middle IR band (2.08-2.35 μm) best expressed the variability in the reflectance of these soils in relation to the iron oxide and organic matter present. (See table 9.) The surface soils exhibit decreased reflectance in both the red and middle IR bands with *increasing organic matter content.* The increased iron oxide contents of the subsurface soils lead to increased red reflectance and decreased middle IR reflectance when compared to the corresponding surface soil.

This indicates that eroded phases of these 4 soil series could be distinguished from their noneroded counterparts on the basis of spectral variations attributable to iron oxide content. For the well-drained sandy loam surface soils, spectral separability follows characteristic differences in their organic matter content.

Additional work will examine the spectral relationships revealed by ground-based reflectance studies with actual Thematic Mapper data from the southeastern Alabama area from which samples of the 4 benchmark soil series were obtained.

TABLE 9



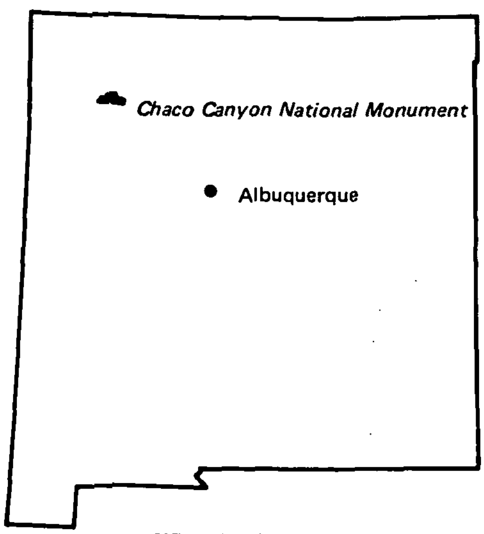
REFLECTANCE OF AIR DRY, UNCRUSTED SOILS DEMONSTRATING INCREASED RED REFLECTANCE AND DECREASED MIDDLE IR REFLECTANCE OF SUBSOILS OVER THAT OF SURFACE HORIZONS.

ARCHEOLOGICAL INVESTIGATIONS

The interface between man-land relationships has been a prominent factor of environmental studies and resource management. With the advent of thermal scanner technology, the observation of these relationships will be enhanced for not only today's and tomorrow's conditions, but it will also hold a potential for increasing the understanding of yesterday's cultural societies. The evidence of past societies is a major consideration in environmental studies when alteration of landscape is required to meet current and future societal needs.

Federal and state regulations protect historic and prehistoric cultural resources. In most states a systematic inventory of cultural resources has never been accomplished because archeologists as a scientific community are relatively unfamiliar with aerial survey, and yet they must thoroughly and systematically perform ground surveys over large tracts of land in relatively short intervals of time. Unfortunately, most historic and prehistoric features are not observable from the ground but are evident only as subtle spectral or spatial phenomena which are, fortunately, potentially observable with remote sensors.

During FY1982, a study was initiated to determine the feasibility of applying new remotely sensed data available from the TM, TIMS, and SIR systems to the archeological inventory problems. The Chaco region in northwest New Mexico, depicted below, has been selected as a primary study area because it encompasses the largest concentration of historic and prehistoric cultural resources in North America. The region includes the Chaco Canyon National Monument which is connected by prehistoric roads to other Anasazi Centers. Of interest in the study is the detection of these roadways and Anasazi settlement ruins.



NEW MEXICO

In 1971, archeologists reviewing aerial photographs taken in 1929 by Charles A. Lindbergh discovered a network of prehistoric highways. These roadways were constructed by the Anasazi culture circa 900 A.D. This society possessed neither the wheel nor beasts of burden. Consequently, the reason for the construction of the roads remains a mystery. One of the striking features of the roadways was their straightness (see plate 10), and in almost all cases the major roadways were 30 feet wide with a dish-shaped cross section. Some ended at a canyon wall, some gradually blended into the natural desert surface, while others extended as much as 65 miles to connect Chaco Canyon with other major Anasazi centers. Over 200 miles of roads have been mapped through the use of aerial photography.

The problem encountered when trying to determine the location of the roadways is that they are not easily seen on the ground. Although a few segments stand out distinctly at dawn or dusk at certain times of the year,

they are generally invisible from ground level. Despite the difficulty in viewing the roadways, their existence is nevertheless supported through direct association with stairways, causeways, roadcuts, ramps, walls, curbs, changed vegetation, ceramic artifact distribution, and their alignment with outlying structures. Most of the roadways survive today through the combined processes of erosion, compaction, vegetation, and the initial prehistoric clearing of loose soil and debris to the roadway borders. All that remains of the roadways today is an almost imperceptible depression.

In April of 1982, NSTL/ERL acquired TMS data at 10-meter and 30-meter cell size resolution over the Chaco Canyon study area. Analysis of the 10-meter data indicated that the thermal band (10.4-12.5) offered the optimum results for the detection of prehistoric roadways and subterranean features. Although band 2 (0.52-0.60 microns) did detect vegetative differences in some of the roadways, there was some confusion in identifying which were roadways and which were actually gulleys. The thermal band also permitted the detection of the exterior walls of the D-shaped pueblos themselves, whether the walls were 30-50 feet high such as at Pueblo Bonito or 1-3 feet high as at Pueblo Alto. (See plate 10.) This phenomenon apparently occurred as a result of the wall dissipating heat through the night, and then through midday these cooler temperatures caused a thermal difference relative to the surrounding terrain. Additional areas of interest include the detection of subterranean walls emanating from Pueblo Alto and the location of a prehistoric agricultural field outside of Chetro Ketl.

The initial success of the one thermal band increased the potential utility of the 6-band Thermal Infrared Multispectral Scanner (TIMS) for archeological reconnaissance. Consequently, in August of 1982, 5-meter day and night TIMS data were acquired over Chaco Canyon. The improved spatial resolution and band-widths of the TIMS greatly enhanced the prehistoric Anasazi roadways as well as subterranean archeological features. Analysis of the TIMS data indicates the existance of previously undiscovered archeological features such as subterranean walls, trash middens, and occupational sites. While both the day and night TIMS data reveal the existence of a prehistoric agricultural field adjacent to a major pueblo complex, the nighttime TIMS data delineate the exact perimeter of the field. Substantiation of these predicted areas awaits confirmation through future methodological excavations by the National Park Service.

Future research efforts include the analysis of SIR-A data. The potential application of SIR data for archeological investigation has been shown in the Sudanese desert where SIR-A data detected subterranean features.

In FY1983 the overall goal will be to develop information extraction analysis techniques that will expedite the survey and excavation of archeological sites thereby avoiding costly delays for developers. The resultant cultural feature detection methods will provide analytical models for immediate application to other threatened archeological areas around the globe. Other potential applications include investigations of Inca calendar systems in Peru, roadway systems within Jerusalem and megalithic occupational areas in Great Britain.

FUNDAMENTAL RESEARCH: SCENE-TO-MAP REGISTRATION

This fundamental research investigation was approved and initiated in FY1982. The investigation focuses on Landsat MSS and TM data scene-to-map registration procedures and accuracy. Specifically, this investigation examines the geometric distortions associated with Landsat Multispectral Scanner (MSS) data in the P-format (Pre-georegistered data) and also the optimum method for registering data from the Thematic Mapper (TM).

INTERFACE MEASURATION TECHNIQUES

Research effort has been expended on the development of a Wetlands Productive Capacity Model (PMC), discussed elsewhere in this report, which uses remotely sensed indicators of primary productivity and other parameters to measure the contribution the coastal wetlands make to the marine resources food chain. As potential components of this model, interface length (shoreline) and interface density (complexity) algorithms were perfected and tested. Since they are derived from remotely sensed data, the algorithms can ascertain the interface length and interface complexity between any two land surface feature classes; however, their testing and analysis were based on the PCM scenario.

INTERFACE LENGTH

The interface length program (ELAS software module SLIN) was optimized to measure shoreline length in georegistered Landsat MSS data using logic based on the data in defined, square-shaped cells. When Landsat surface feature classes have been aggregated into the two basic classes of land and water, as shown in Plate 11, the SLIN module identifies (in the digital data) the land-water boundary, delineates the actual interface elements for mapping purposes, and measures the interface length values. In an accuracy test of the module on 24 test polygons of varying size and shape but with known lengths, the algorithm was accurate to 4 parts in 1,000. The description of this software program has been documented in ERL Report No. 208, "SLIN - A Software Program to Measure Interface Length."

INTERFACE DENSITY

The interface density measurement is defined as the interface length per unit area, where interface length is determined by the above mentioned SLIN module. Interface density can measure the complexity of the boundary between any two adjacent classes (as derived in a Landsat classification), whether they occur in a land-water context or in a land-land application. The algorithms were designed to provide a method for assessing the importance of boundaries in an applied remote sensing context.

Three versions of interface density have been developed and tested, each providing some variation to the density measurement. ELAS module SLD3 (plate 11) only computes interface complexity values for pixels at the land-water boundary (or at the boundary between 2 designated classes in a land-land application). Modules UGSD and SLID compute complexity values for all of the pixels within a specified size observation window, with their variation dependent on the surface feature composition within the reference area used in the density calculation. Plate 11 provides examples of the UGSD and SLD3 versions.

An example analysis was conducted on the utilization of interface length and complexity in predicting the yield of selected aquatic fish and shellfish populations in the Apalachicola Bay of northwest Florida. Regression analysis of this data showed the interface complexity to be significant, accounting for 49-87% of the total variation in shellfish and finfish yields. The details of module rationale, operation, and analysis are given in ERL Report No. 210, "Software Programs to Measure Interface Complexity with Remote Sensing Data, with an Example of a Marine Ecosystem Application."

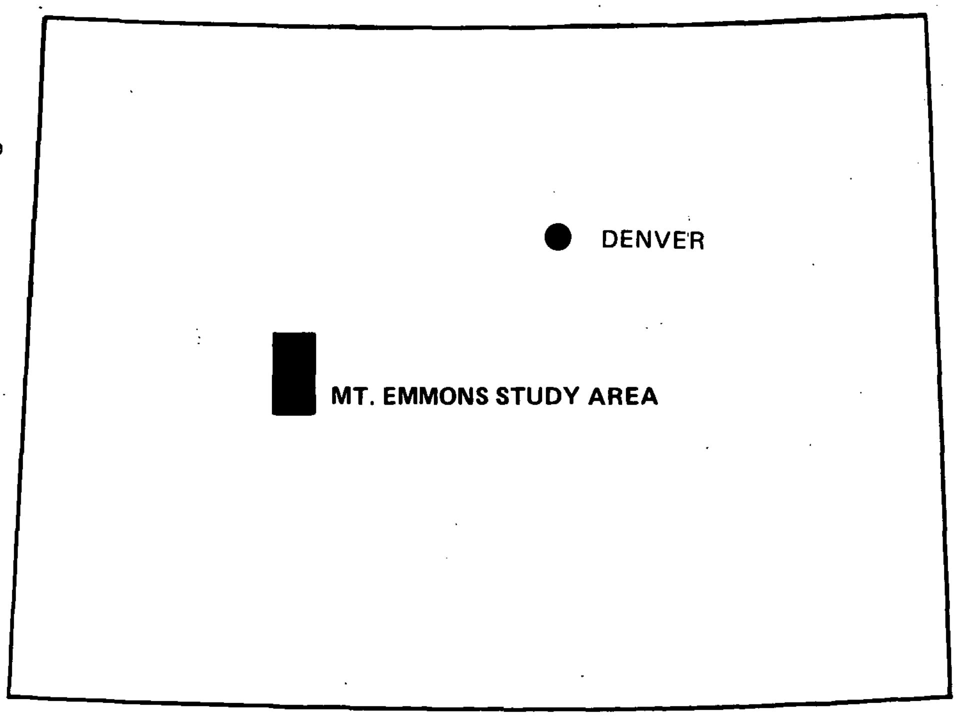
NON-RENEWABLE RESOURCES STUDIES

NSTL/ERL's research activities were expanded in FY1981 to include nonrenewable resources studies. Now in its second year, this effort encompasses (1) geological mapping and (2) geobotanical applications.

GEOLOGICAL MAPPING

The primary objective of the geological mapping effort is to determine the utility of Thematic Mapper data (initially simulated) in the detection and mapping of hydrothermally altered characteristics of specific ore systems in rugged terrains with moderate to no vegetative cover. A second objective is to use the data for general lithologic mapping.

TMS data were acquired over an area of Mt. Emmons, Colorado, molybdenum ore body and the surrounding mountainous environs during September, 1981. Of significance was the fact that in February, 1982, a letter of agreement was signed between NASA and AMAX, Inc., making this a NASA/AMAX cooperative project. Since topographical effects were expected to be significant in all subsets of the TMS data, the data were integrated with digital NCIC elevation data. Geochemical and geophysical information supplied in part by AMAX is also being used.



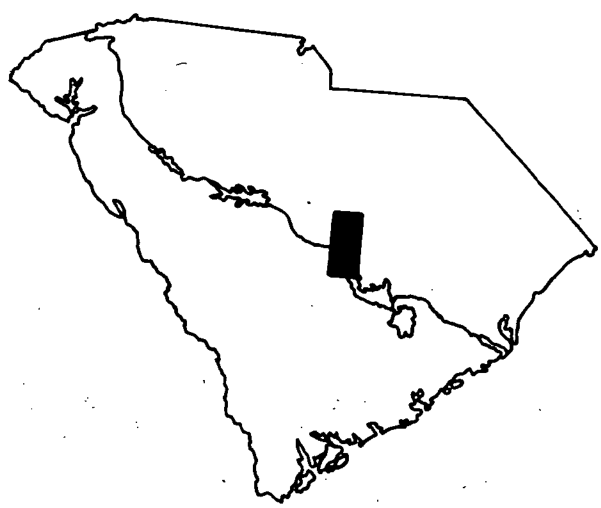
COLORADO

Data processing emphasizes digital processes to create an enhanced image product. Data parameters from areas with partial and no vegetative cover have been separated and processed independently by different techniques. Software routines in the ERL ELAS system, such as band ratioing, contrast stretching, selective filtering, and "true color" product generation, are being applied to the data from barren areas. From the data of the vegetated areas, the distribution of flora is being modeled in terms of elevation and aspect so that the lithologic control of vegetation can be estimated. At the completion of the separate processing, the subsets will be combined. Shown in plate 12 is a representative segment of the Mt. Emmons TMS data that has been decorrelated to enhance visual image analysis of lithology and vegetation.

A field survey was made late in the fourth quarter of FY1982 to validate the initial investigation results and to provide the necessary ground truth to continue more exacting processing approaches in FY1983. The investigation will shift to the analysis of actual TM data as they become available.

GEOBOTANICAL APPLICATIONS

Complementing geological mapping is the geobotanical applications investigation of using TM data (also presently through simulation) for the detection of mineralization in vegetated terrains. The emphasis is on ore-bearing terrains in areas that are moderately to heavily vegetated.



Haile, South Carolina, Study Area

Geobotanical methods involve the use of surface vegetation to help identify the nature and properties of the substrate. The two aspects that are believed to be identifiable by remote sensing are (1) differences in plant community structure and (2) the effects of mineral stress in the plant community. Data processing procedures are concentrated on the development of spectral pattern recognition outputs, since pattern recognition is effective in emphasizing minute detail in spectral data and therefore is capable of finding subtle geobotanical relationships.

TMS data were acquired for a study area near Haile, South Carolina, in early April, 1982. The Haile area was chosen because of the associated interface between pyroclastic rocks and argillites, which is typical of massive sulfide deposits. In principle, the ability to accurately map these lithologic contacts and any alteration in the rocks by using remote sensing data would greatly enhance the possibility of discovering a major, massive sulfide deposit.

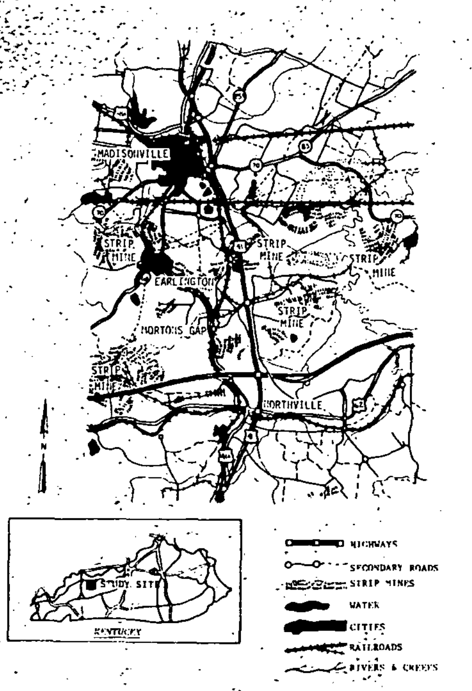
The data processing effort has progressed from the initial spectral data processing to a preliminary surface feature classification product. This product will be field analyzed when the general ground truth data is acquired late in the fourth quarter of FY1982. TMS data analysis will continue into FY1983, and, as in the geological mapping study, this investigation will shift to the utilization of actual TM data as they become available.

MICROWAVE SENSOR ANALYSIS

Under RTOP 677-21-21 Multisensor Land Resources Studies, research continued in FY1982 on Microwave SAR and Landsat MSS data integration. Specifically, the project in western Kentucky, initiated in FY1981, was completed. Seasat L-band and aircraft X-band dual polarized Synthetic Aperture Radar (SAR) data of the Western Kentucky Coal Region were examined, preprocessed, and combined with the Landsat Multispectral Scanner (MSS) data to form a 7-band multisensor data set. Multisensor data analysis included separate evaluation of the 3-band SAR data, the 4-band MSS data, and the combined 3-band SAR and Landsat MSS bands 5 and 7 data. Techniques for information extraction consisted of digital count value comparison and spectral pattern recognition classification for the SAR and MSS data. Plate 13 is a representation of the statistics and final classification.

The analysis of classified data sets showed that the 3-band SAR data contain a moderate discrimination accuracy value for the strip mine land cover classes but a low accuracy value for the residential classes. The 4-band MSS data contained a low classification accuracy value for the strip mine and residential classes. The integrated 5-band SAR/MSS data showed that significant improvement in classification accuracy was obtained for both strip mine and residental classes. Overall classification improvement is given in table 10. The investigation was documented in ERL Report No. 207, "Analysis of Data Acquired by Synthetic Aperture Radar and Landsat Multispectral Scanner Over Western Kentucky Coal Region." Results were presented as a paper in the Eighth International Symposium of Machine Processing of Remote Sensing Data in June 1982.

Also, in FY1982 Shuttle Imaging Rådar data over a study area in southern Alabama have been acquired and converted into computer-compatible tapes, so that processing can be initiated. The processing and analysis of this data for both the ascending and the descending passes over the agriculture and forestry-oriented study area will be the major thrust in FY1983.



Western Kentucky Coal Region Study Site

TABLE 10

Land Cover Types	SAR 3 Band	MSS 4 Band	SAR/MSS 5 Band
Pasture	46.9	81.3	96.7
Forest	92.3	88.0	92.5
Residential	10.0	59.4	79.0
Soybean Field	89.5	59.4	90.9
Corn Field	88.3	32.5	99.0
Water	99.9	97.4	99.9
Strip Mine	64.9	47.7	77.4
Overall	48.2	64.2	81.1

- JOINT RESEARCH PROJECT

    - Crop Mensuration and Mapping
    - Timber Resources and Inventory
    - Wetlands Productive Capacity Modeling
    - Farmers Information and Resource System
    - Cotton Acreage Inventory

JOINT RESEARCH PROJECT

Page intentionally left blank

Page intentionally left blank

CROP MENSURATION AND MAPPING

With respect to agricultural remote sensing applications, success with Landsat MSS data has required the analysis of sequential data sets acquired at optimum times throughout the corp growing season and integration of other environmental data, such as soils, to enhance separation of crop types. The objective of the Crop Mensuration and Mapping project is to determine the capability of Thematic Mapper data to improve the accuracy while reducing the amount of data and processing time required for crop type discrimination and areal measurements. In cooperation with International Harvester, intensive study areas in Poinsett County Arkansas, were selected to investigate TM data for mapping crops.

Poinsett County lies partially within the floodplains of the Mississippi and St. Francis Rivers and the well-drained uplands west of Crowley's Ridge. The land area of the county is approximately 486,208 acres (196,845 ha) with 84% of this acreage maintained in farmland. Elevations above mean sea level in the county range from about 400 feet on Crowley's Ridge to about 140 feet near the St. Francis River at the southern boundary of the county. County topography can be divided into 3 distinct sections: the level bottomlands in the east; the moderately steep Crowley's Ridge; and the moderately sloping upland plains to the west.

This western area provided the basis for an MSS and TM preliminary comparison. Landsat MSS data sets were obtained for (1) pre-planting conditions and winter wheat mapping (February 26, 1981, ID#2222715584); (2) midseason vigor (July 20, 1981, ID#2237115563); and (3) senescence (September 30, 1981, ID#2244315554). The dates were used to give the broadest possible range of spectral values for the target land cover types. MSS bands 5 and 7 from each data set were registered to create a single 6-channel data set, and an automatic technique using a 3 by 3 sliding window developed 30 spectral signatures. These spectral responses were classified, and the resulting classes were identified by specific land cover types. The 30 spectral classes developed for the study were related to specific land cover types using ground truth, aerial photography, or crop production records.

During this investigation, the naming and verification of the spectral classification were made with a series of ground truth polygons delineated from aerial photography and USGS 7.5 minute quadrangle maps. Polygons used in the ground truth or class naming and verification exercises were randomly selected from a 3,200 acre (1,280 ha) area within the study area; these 3,200 acres (1,280 ha) encompassed 20 quarter-sections of land. Half of the polygons were utilized for class naming, and half were used for accuracy assessments. Aerial photography employed as ancillary information helped to define field boundaries within each quarter section. Only interior field pixels were digitized and used for data analysis, thereby reducing spectral confusion within the polygons. Class naming polygons totaled 52, and verification polygons totaled 56. Crop statistics compiled by the Argicultural Stabilization and Conservation Service were used to name the agricultural polygons for the 1981 growing season. Aerial photography and field observations were utilized to identify the nonagriculture polygons.

The 52 class naming polygons were identified and used to group the 30 MSS spectral classes into 6 land cover categories:

1. Hardwood
2. Fallow
3. Rice
4. Soybeans
5. Winter Wheat/Soybeans
6. Water

The overall accuracy of the land cover map in plate 14 was determined using the 56 verification polygons coded according to land cover type, to construct an accuracy table. Comparisons were then made between the polygons in the accuracy table and the corresponding pixels in the classification.

Table 11 groups the accuracy assesments according to land cover type. Overall accuracy of the land cover classification based on MSS data was 80.91% correct. The highest percentages of classification accuracy were recorded

TABLE 11

LANDSAT MSS MAPPING ACCURACY

CLASS	% CORRECT
1. Hardwood	100.00
2. Fallow	0.00
3. Rice	98.74
4. Soybeans	89.69
5. W/Wheat/Soybeans	18.63
6. Water	22.81

		LAND COVER CATEGORIES						
		HARDWOOD	FALLOW	RICE	SOYBEANS	WINTER WHEAT/ SOYBEANS	WATER	NO. OF PIXELS
		1	2	3	4	5	6	
HARDWOOD	1	307 100.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	307
FALLOW	2	0 0.00	0 0.00	206 99.52	1 0.48	0 0.00	0 0.00	207
RICE	3	0 0.00	0 0.00	2191 98.00	28 1.26	0 0.00	0 0.00	2219
SOYBEANS	4	0 0.00	0 0.00	149 10.31	1296 89.69	0 0.00	0 0.00	1445
WINTER WHEAT/ SOYBEANS	5	0 0.00	0 0.00	41 8.78	339 72.59	87 18.63	0 0.00	467
WATER	6	44 77.19	0 0.00	0 0.00	0 0.00	0 0.00	13 22.81	57

PERCENT CORRECT OVERALL 80.91

for the hardwood, rice, and soybean categories with percentages of 100, 98.74, and 89.69, respectively. Low accuracies were recorded for double-cropped areas of winter wheat and soybeans (18.63) and water (22.81). Seventy-three percent of the double-cropped areas of winter wheat and soybeans were classified as soybeans.
The relatively smaller fields of winter wheat in the study area did not contribute a significantly large number of interior field pixels for signature development. Also, impoundments in this area are normally smaller than 10 acres and are usually bordered by hardwoods.

The 3 by 3 pixel sliding window, therefore, did not find a significant number of water pixels for signature development. Reduced availability of interior field pixels will result in errors of omission for small land cover features, especially when applying the sliding window approach (Stoner, et. al. 1981). This problem can be alleviated to a certain degree by utilizing a pixel-by-pixel analysis which will gather a sufficient number of small field pixels during signature development. No mapping accuracies for the fallow category have been listed in table 10 because no sample ground verification polygons were selected for this class.

A TM data set acquired on August 22, 1982, was used for the comparison and was subjected to the same automated signature development algorithm for derivation of spectral signatures. It is significant to note that at least 1 year had elapsed between MSS and TM data acquisition for the study area.

Bands 2, 4, and 5 were used to develop signatures from the data. The other 4 channels were not input, since previous analysis indicated that separation of agricultural cover types with bands 2, 4, and 5 produced statistically better results overall than those produced using all 7 bands of information.

The unsupervised statistical development technique resulted in 43 spectral signatures. All ground truth polygons evaluated during the MSS analysis were revisited in August, 1982, and were used to: (1) establish the relationship of spectral signatures with specific land covers; and (2) develop estimates of accuracy. Because land uses in the study area had changed in the intervening time period between MSS and TM data acquisition, the distribution of land cover types was not the same for TM analysis. Consequently, the 43 spectral signatures developed from the data were identified as belonging to 1 of 5 land cover categories: (See plate 14.)

1. Soybeans
2. Rice
3. Fallow/Bare Soil
4. Hardwood
5. Water

As in the MSS analysis, relationships were established between the TM classification and the ground verification polygons selected for the study area. The accuracy results are presented in table 12.

The accuracies listed in tables 11 and 12 have been used to compare the performance of the MSS versus the TM within the Poinsett County study area. Results from a Newman-Keuls test of comparative accuracies illustrate that: (1) the TM did significantly better than the MSS in an accuracy assessment of the fallow and water classes; (2) the MSS and TM performed equally well (i.e., no statistically significant difference in accuracies) in the soybeans, rice, and hardwood categories; and (3) most importantly, the TM performed significantly better than the MSS in an overall comparison of accuracies. These results are made even more interesting when it is considered that only 1 date of TM data has been used for analysis, as opposed to the 3 dates of data (February, July, and September) utilized in the MSS evaluation.

TIMBER RESOURCES AND INVENTORY

The objective of the Timber Resources Inventory and Monitoring project with International Paper Company is to determine the informational content of Landsat TM data for mapping forest stand composition and silvicultural activities. Past experience with Landsat MSS has had limited success in discriminating forest resources beyond James R. Anderson's Level I and Level II classification system ("A Land Use and Land Cover Classification System for Use with Remote Sensor Data," by Anderson, et. al.). Separating

CLASS	% CORRECT
1. Hardwood	100.00
2. Fallow	92.55
3. Rice	99.42
4. Soybeans	94.77
5. Water	100.00

TABLE 12

LANDSAT TM MAPPING ACCURACY

		LAND COVER CATEGORIES					
		HARDWOOD	FALLOW	RICE	SOYBEANS	WATER	NO. OF PIXELS
		1	2	3	4	5	
HARDWOOD	1	194 100.00	0 0.00	0 0.00	0 0.00	0 0.00	194
FALLOW	2	0 0.00	149 42.55	0 0.00	1 0.62	0 0.00	150
RICE	3	9 0.19	0 0.00	4783 99.42	18 0.37	0 0.00	4810
SOYBEANS	4	45 0.91	0 0.00	212 4.30	4672 94.77	0 0.00	4929
WATER	5	0 0.00	0 0.00	0 0.00	0 0.00	83 100.00	83

PERCENT CORRECT OVERALL 97.06

deciduous from coniferous forest, for instance, has been accomplished through the analysis of seasonal data sets. In some cases, canopy density levels have been detected, but not at the density levels that are important to forest management personnel.

At the initiation of the joint project between International Paper Company (IP) and NASA/NSTL/ERL, IP defined the forest information requirements which will be addressed during this particular research effort:

- Forest Stand Condition
  - Composition
  - Density stratification
  - Relative age
- Silvicultural Activities
  - Planting and restocking
  - Precommercial thinning
  - Harvest
  - Site preparation
- Forest Conversion
  - Change to/from forested lands

A study area in Baldwin County has been selected to develop and experi mentally test TM data information extraction techniques. For this area, IP currently has data bases developed through conventional aerial and ground surveys which will provide the basis for evaluating the results. Information extraction techniques include spectral and spatial pattern recognition with particular emphasis on contextural and shape classifiers.

Preliminary results using the Thematic Mapper Simulator (TMS) indicate success in separating loblolly pine *(Pinus taeda)* from other southern yellow pine. (See plate 15.) Using band 2 (.52 µm - .62 µm) loblolly response was greater than stands of longleaf pine *(Pinus palustris)*. In addition, the loblolly pine response was lower in the infrared bands than slash pine *(Pinus elliottii)*.

Atlantic white cedar *(Chamaecyparis thyoides)* is a conifer that exists with hardwood species in acid swamps and wet bogs. An association of Atlantic white cedar and hardwood was separated using the thermal band (30 meter resolution). The response was lower in the thermal channel than in other swamp hardwood species.

Additional preliminary results appear promising regarding silvicultural activities. As shown in plate 15, site prepared areas were separated from new pine plantations using band 3 (.63 µm - .69 µm) and the thermal channel (10.4 µm - 12.5 µm). A site prepared area using a double disking technique was separated using the thermal band. Double disking, a very expensive method of site preparation, is associated with intensively managed forest plantations. Fire damaged stands were separated using band 4 (.76 µm- .90 µm). A low response indicated an absence of vegetation. These preliminary analysis results were accomplished using a February 1982 TMS data set. Seven channels were classified using ERL standard unsupervised techniques.

WETLANDS PRODUCTIVE CAPACITY MODELING

The 4-year Wetlands Productive Capacity Modeling joint research project, initiated in FY1982, encompasses the research and development of Thematic Mapper (TM) satellite technology to determine the value of wetlands to living marine resources. The project is a cooperative endeavor between the NOAA-National Marine Fisheries Service's (NMFS) Southeast Fisheries Center and NASA/NSTL/ERL. The TM technique developed within the scope of this project will be tailored to NMFS research and management responsibilities. Its usefulness will be evaluated by the same criteria.

The Wetlands Productive Capacity Model, a remote sensing-based model, is being refined, tested, and analyzed to determine if derived results can provide quantitative information about the value of wetland habitats to the production of estuarine-dependent fishery resources. TM technology is being directed towards (1) primary productivity assessment and (2) detrital export estimation as variables influencing the determination of the tropic value of wetlands. Another model being developed will describe the energy flow of an estuary to relate detritus exported from the wetlands to the standing stocks of juvenile fish and shrimp. This estuarine model will involve (1) a shrimp productivity index and (2) a detritus availability index.

Technique development is utilizing Landsat MSS data for productive capacity model refinement, TMS data for analysis of TM potential and data processing procedure development, and TM data for testing and evaluating the integrated models. The Calcasieu Lake Basin (plate 16) in Louisiana is the selected study area and is being used in the technique development process.

FARMERS' INFORMATION AND RESOURCE SYSTEM TECHNOLOGY (FIRST)

During FY1982, development and testing of a Geographic Information System (GIS) as part of a research project conducted jointly with Missouri Farmers Association, Inc. (MFA), were completed. A GIS containing Landsat-derived land cover data and map-derived soil survey data was applied to certain agricultural production and distribution problems in the 120,000-acre study area of Darlington, Missouri. Five agricultural management information requirements and the base components that contribute to their estimation are outlined in Figure 3. Data base manipulation for the creation of mapped products illustrating the areal distribution and rank of crop/soil interactions was accomplished with the program DBAS. The information in soil map units was obtained from soil interpretations records and was entered into the data file with the ELAS table editor module, TBED.

Modern soil surveys contain information relating to the productive capacity of each soil map unit for growing specific crops. This information comes from field trials as well as inferences from soils with similar properties. An example of how this information can be used to demonstrate soybean yield potential on Landsat-identified soybean fields is demonstrated by the following examples. In this case, the basic soil map units, representing soil phases, were evaluated to possess 21 levels of yield potential (at high management levels). In plate 17, the Landsat-derived land cover map was used to extract data from only those land areas representing the location of soybean fields in 1980. Field patterns are obvious as is the concentration of high yielding soybean fields in the level stream bench area contrasted with the lower yielding soils on the upland sites. It should be stressed that this data base application does not involve yield modeling, but rather attempts to rank the soils on which soybeans were grown during the 1980 growing season in the order of their inherent productive capacity. For a "normal" growing season, these yield levels would be expected.

The market for fertilizer sales in a given area can be estimated by taking average fertilizer application rates by crop (according to MFA, Inc., sales records) and specifying these rates for each Landsat-identified crop type. For example, in plate 17, nitrogen fertilizer rates rank individual crop types from low to high applied nitrogen needs. Soybeans, which are capable of meeting their nitrogen needs by association with nitrogen-fixing rhizobia bacteria, do not require application of nitrogen fertilizer. However, inoculant containing effective rhizobia strains may be added to the soybean seeds at planting time and would be of interest to farmer co-operatives who sell the inoculant packets.

FIGURE 3

Contribution of data base components to agricultural management information requirements

		SOIL MAPPING UNIT LOCATION AND ATTRIBUTES						
REQUIREMENT	LAND COVER LOCATION LANDSAT-DERIVED	ORGANIC MATTER CONTENT	SURFACE TEXTURE	SLOPE	AVAILABLE WATER CAPACITY	INTERNAL DRAINAGE	PERMEABILITY	EXPECTED YIELDS AT HIGH LEVELS OF MANAGEMENT
1. Productive Capacity								
Soybeans	Soybean Field Location							Unique for each Soil Phase
Corn	Corn Field Location							Unique for each Soil Phase
2. N,P,K Fertilizer Potential	Average Usage by Crop from Sales Records							
3. Herbicide Potential								
Atrazine	Corn Field Location	<5%-low rate >5%-high rate	Coarse-low rate Medium-high rate					
Trifluralin (Treflan)	Soybean Field Location	<5%-low rate >5%-high rate	Medium-low rate Heavy-high rate					
4. Irrigation Suitability	Location of Cultivated Fields			0-5% Suitable 5-9% Restricted >9%-Unsuitable	<4" H_2O /36" Depth Unsuitable	Poor Drainage Unsuitable		
5. Trafficability for Spring Planting	Row Crop Location		Swelling Clays Restricted				Very Slow-Restricted Moderate-Unrestricted	

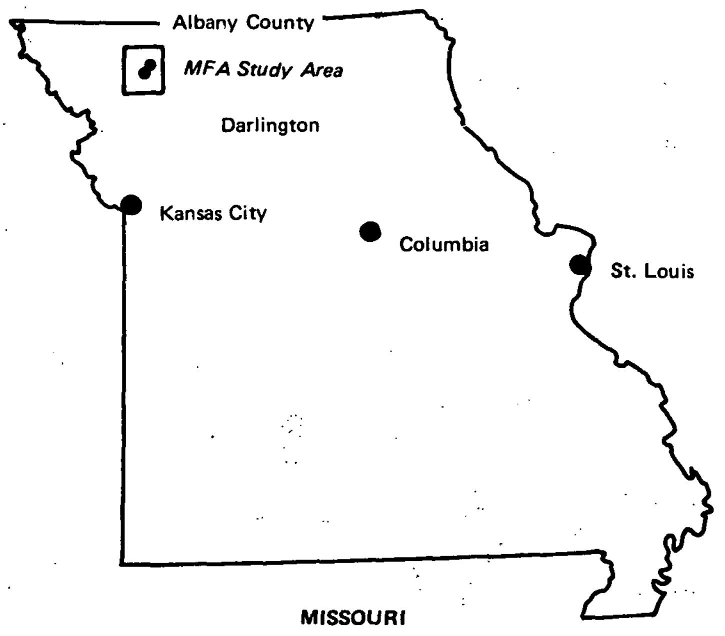
According to the area tally, 32,686 acres of land would have had sales potential for soybean inoculant in this area in 1980. Likewise, total nitrogen fertilizer potential by crop would have been as follows: wheat, 130 tons; sorghum, 11 tons; corn, 1,150 tons. Phosphorus and potassium fertilizer potential could be estimated in the same manner by extracting crop location with Landsat data. Actual fertilizer recommendations by field according to soil map unit characteristics were not made, but will be possible when state-wide soil test results are recorded and compiled.

A major input in grain framing is the vast array of selective herbicides for controlling specific weed types in specific crops. In a recent year, 99% of the corn grown in Missouri had chemical weed control, while 96% of the soybeans had applications of herbicides. Effective weed control required adjustment of herbicide application rates according to differences in soil organic matter and clay content from field to field.

As much as 85% of the land in Missouri planted with corn uses some form of atrazine herbicide alone or in combination with other herbicides. A widely used herbicide in soybeans is trifluralin (Treflan). Both of these herbicides have higher label rates when used on soils with greater than 5% organic matter content. The land areas which would require these higher application rates can be shown (plate 17.) using the information contained in the data base. In this illustration, only those Landsat-derived land areas planted to row crops are shown, while the soils with high absorptive capacity for atrazine and trifluralin are shown in the darker color. A total of 41,575 acres could use the lower application rates, while 9,045 acres would require the higher application rates for effective weed control. This translates to a market potential for 59,665 pounds of atrazine or 42,487 pounds of trifluralin if either herbicide is used exclusively on its adapted crop. If this simplified example were not the case over a typical trade area, the actual proportions of the many herbicides sold could be factored into the data base to provide more realistic market potential figures.

Another application of the data base would be to show those land areas that, because of their soil characteristics, are suitable for installation of center pivot or traveling gun irrigation systems. Water source is not considered a limiting factor. Soils that are well suited for these irrigation practices are generally on level ground with adequate available water capacity and good drainage. Of this total land area (plate 17) of 54,084 acres, 9,628 acres are well suited for irrigation, 19,729 acres are restricted because of slope and aeration limitation, 15,994 acres are restricted because of steep slopes, 500 acres are restricted because of soil inability to store water and aeration problems, and 1,767 acres are unsuitable because of a combination of these limiting factors, primarily, steep slopes.

Generally, the highest yields are obtained from corn in this part of the Midwest if it is planted before May 15. As a rule, if corn is not planted by this date, a farmer will plant soybeans or sorghum. The reason this might occur is the difficulty in moving planting equipment into a slow drying field during a wet spring. The soil map in plate 17 provides information on the suitability of different soils to support the heavy equipment used to plant row crops.



In this example, the Landsat-derived land cover map is again used to delineate row crop areas, and the digital soil map separates these areas into 4 rates of soil dry-down. Soils with swelling clays which are very slowly permeable have very slow drying rates, indicated in red. These 713 acres would be difficult to plant with corn during a wet spring. Under very wet conditions, 28,178 slow-drying acres may not be capable of being planted with corn that season. With knowledge of local weather conditions, managers should be able to assess planting delays and arrange for appropriate products as planting intentions are changed. Additional information about the project can be found in NSTL/ERL Report No. 205, "Agricultural Land Cover Mapping in the Context of a Geographically Referenced Digital Information System."

COTTON ACREAGE INVENTORY

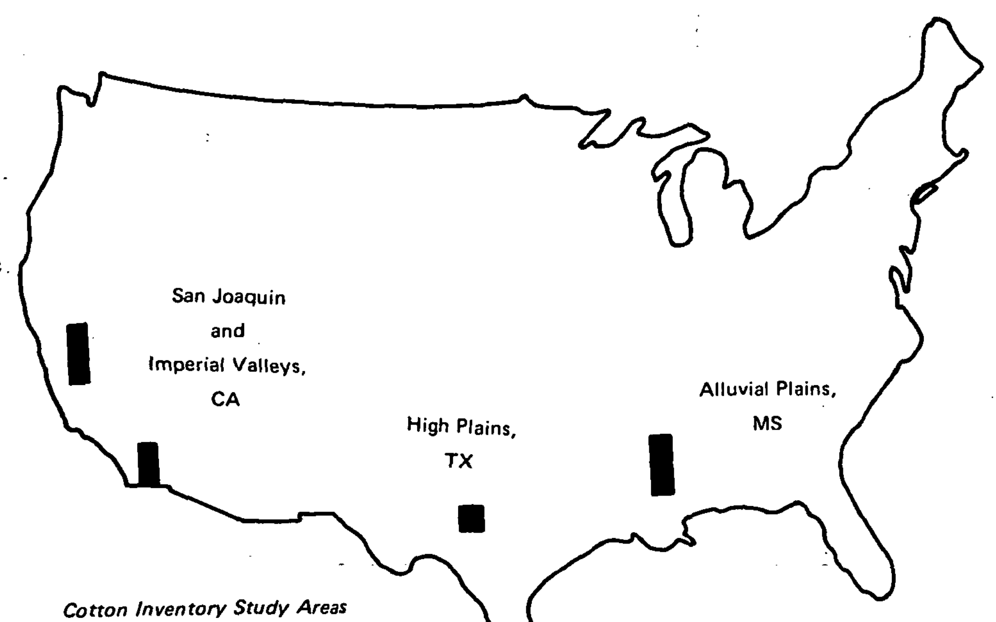
The objective of the cooperative project with Cotton, Inc., was to develop infomation extraction techniques to separate cotton from other land covers. Study areas representing different environmental regimes across the cotton growing region of the United States have been examined to develop a Landsat-based cotton acreage inventory system. These sites are the Imperial and San Joaquin Valleys of California, the Alluvial Plains of the Mississippi River in Mississippi, and the southern High Plains in Texas.

The various aspects of the system that are included in this effort are the development of techniques for the following:

- Using Landsat MSS to mask out or eliminate non-cultivated areas such as forest and water
- Performing linear transformation (modified Kauth-Thomas) of Landsat MSS to derive "greenness" and "brightness" components to reduce the dimensionality of the data for sequential analysis
- Overlaying of Landsat data required at different times during the growing season to create a multidate data set in order to analyze spectral changes during the growing season
- Use of automated signature development and conventional maximum-likelihood classifiers to identify cotton fields from the multidate data set through reference to crop calendar information

The interpretation of Landsat data will permit the identification of the non-cotton production regions, which are the greatest source of omission error (80-90%), and any improvement will result in the improved cotton acreage inventory.

A single-date, 4-channel classification procedure using a non-cotton mask derived from multitemporal data can be used to reliably map cotton in desert regions. With improvements in the non-cotton mask, the potential exists for this technique to work well in humid and semi-arid cotton production regions. The accuracy of identification tends to stabilize when cotton reaches the first flower stage of growth. Cotton, Inc., is preparing a final report incorporating the detailed results of this work.



Cotton Inventory Study Areas

- **TEST AND EVALUATION**
  - **Southern Test and Evaluation Program (STEP)**
    - **Gulf Coastal Plain**
    - **Southern Appalachian Highlands**
    - **Interior Plains**
    - **Southwest Semi-Arid Lands**
  - **Additional Technology Evaluation Activities**

TEST and EVALUATION

Page intentionally left blank

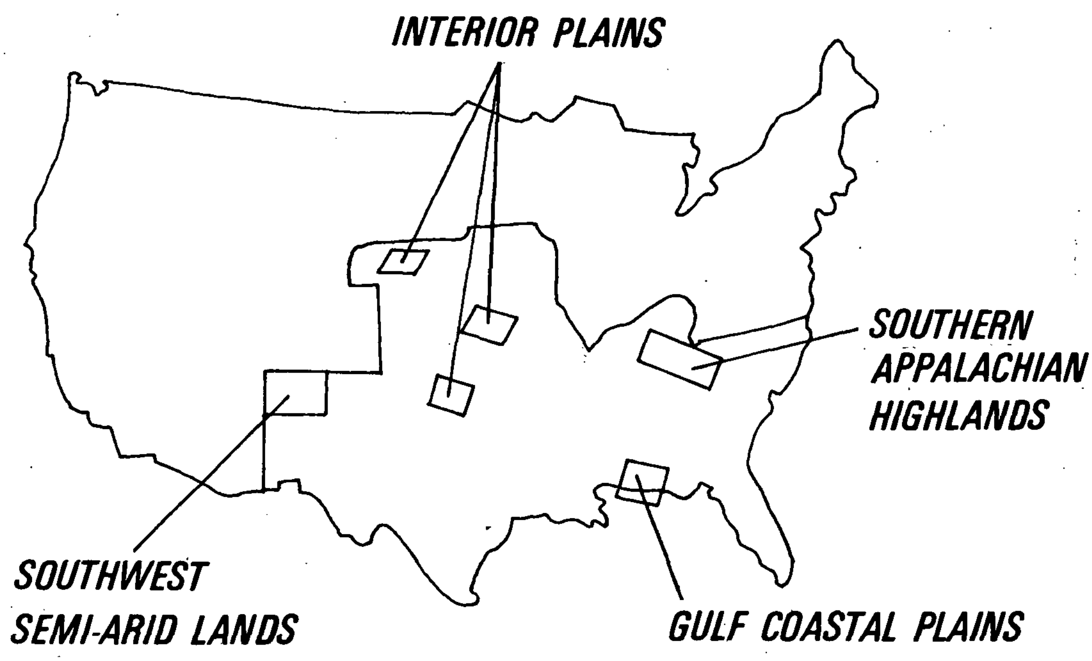
Page intentionally left blank

The Test and Evaluation program has been designed to complete the technology research and development process within NASA by integrating, testing, and evaluating the experimental results of fundamental/applied research and system development programs discussed in the previous sections.

NASA/ERL's role in NASA's Test and Evaluation program capitalizes on its experience and expertise gained by testing and evaluating Landsat MSS technology against resource management information requirements of the non-NASA user community during NASA's Regional Applications program. While previous tests concentrated on Landsat MSS technology, the current emphasis is focusing on Landsat Thematic Mapper data, Shuttle Imaging Radar data, advanced information extraction techniques, and improved systems for processing this new data as well as handling other disparate types of data for environmental modeling.

SOUTHERN TEST AND EVALUATION PROGRAM (STEP)

As a regional center, NSTL/ERL's Southern Test and Evaluation Program (STEP) is responsible for establishing permanent test areas within its 17-state region to evaluate the incremental improvements of advanced technology and for capitalizing on the expertise available in the user community to validate satellite-related technology in a non-NASA environment. During FY1982, 4 permanent test areas, depicted below, were selected within NSTL/ERL's region as representative of the major environmental and cultural differences affecting the applicability of satellite remote sensing technology to earth observations: Gulf Coastal Plain; Southern Appalachian Highlands; Interior Plains; and Southwest Semi-Arid Lands. Each permanent



test area will be utilized to test and evaluate those technologies applicable within the area.

- Gulf Coastal Plain - for county and municipal level area analysis typical of developing coastal/urban environments
- Southern Appalachian Highlands - for regional inventory in diverse terrain and site-specific thematic mapping
- Interior Plains - for range and agricultural condition assessments and change detection
- Southwest Semi-Arid Lands - for large area inventory monitoring of land disturbances using high speed data processing techniques

Major technical issues to be addressed in varying degrees from one area to another include data compression, multisensor data merges, multidata integration, and disciplinary modeling.

GULF COASTAL PLAIN

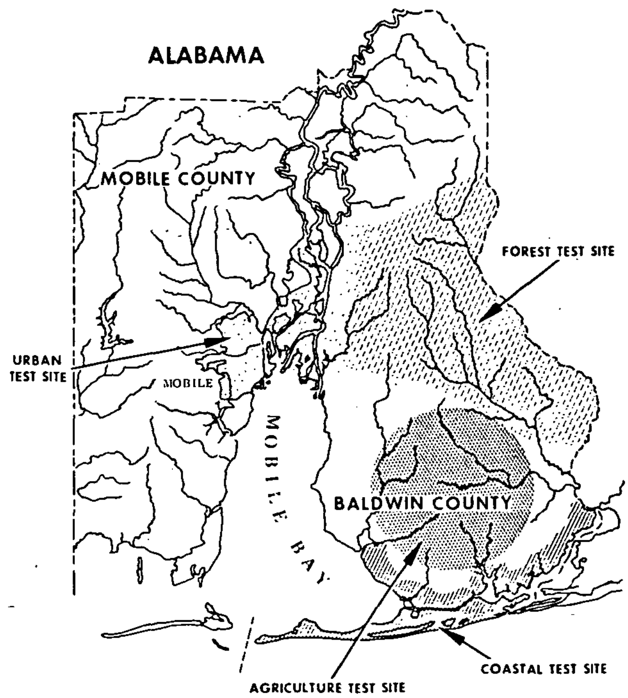
Baldwin and Mobile Counties, Alabama, have been selected as representative of the Gulf Coastal Plain test area. The ground cover conditions which occur throughout the region include coastal shoreline, forested and non-forested wetlands, agricultural areas, monoculture southern yellow pine forests, and rural settlement patterns in transition to larger populated centers.

Coastal locations and low-lying drainage areas for major river systems pose recurring problems with flooding, causing wide-spread damage and loss of life and property. Competition for land has accelerated as migration continues to the sunbelt with steadily increasing demands for recreational, residential, and industrial development. The capability of coastal resources to absorb growth and the need for coastal counties to identify suitable lands for development have become major areas of concern for resource planners and managers at all levels of government.

These characteristics and resource issues provide the technical framework for testing and evaluating remote sensing technology within the Gulf Coastal Plain test area. Emphasis for the test area will address resource information requirements at the county level and the extension of satellite technology to subcounty area analysis.

Particular focus will be placed on spectral pattern recognition; spatial proximity modeling; stratification methodologies; and multisensor (MSS/TM/SAR) multilayered, multiresolution data overlay and associated registration requirements. Three initial projects are currently underway to test the utility of Landsat TM data for improved discrimination and mapping of coastal wetland ecotypes, forest stands, and urban land use patterns. Landsat MSS baseline classifications were completed during FY1982 for both Mobile and Baldwin Counties and for the disciplinary test sites defined within the counties as depicted below.

GULF COASTAL PLAIN TEST AREA



For the county level classifications, automatic signature development techniques were used to separate the spectral classes which were then classified using a maximum-likelihood classifier. Different approaches were used to develop the spectral signatures for the individual test sites. In the urban test site, the highly industrialized urban core boundary was digitized and used to mask that segment of the data. Spectral signatures were developed both inside and outside the urban limits. After the areas were classified, the statistics were merged to form a single land cover classification.

In the coastal and forested test sites, the layered strata approach in developing spectral signatures was used. For the coastal zone, data within the 25-foot contour interval were classified, thus limiting the confusion which was experienced in the combined upland and coastal classifications. Hydrologic boundaries of the Styx River Watershed were used as the limiting physiographic feature for developing signatures in the forested area.

The first MSS classifications are providing the baselines against which similar Landsat TM techniques will be tested. These MSS baselines will also be used to test advanced MSS techniques. For example, the structure of the coastal project, incorporates Landsat 2/3 MSS and Landsat 4 MSS data to test for continuity of performance and Landsat 4 TM and Shuttle Imaging Radar data to test for incremental improvements provided by new sensor data sources.

The project requirements were identified by defining the resource management issues within the Gulf Coastal Plain region. Working cooperatively with the Alabama Office of State Planning, the issues were prioritized and translated into applications within which the land cover results derived from remotely sensed data can be integrated and analyzed to produce resource management information for the following:

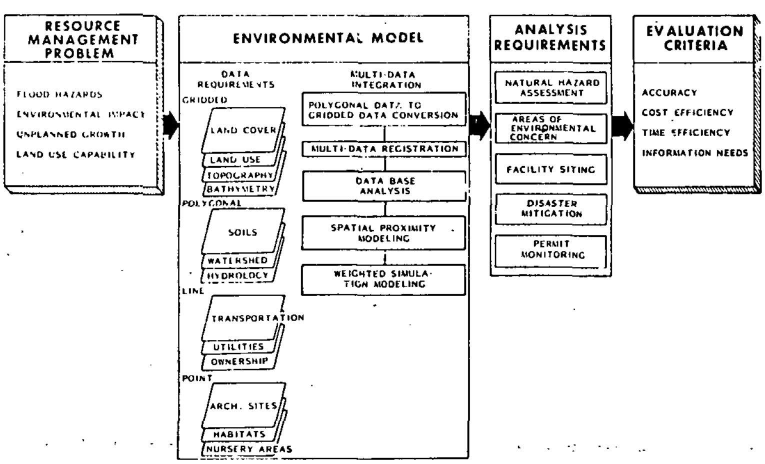
- Coastal land capability assessment
- Forest wildfire occurrence assessment
- Urban flood assessment

The purpose of the application tests is two-fold: (1) to address the interface requirements of integrating sensor data with environmental and cultural data available from existing non-NASA data bases and (2) to address the utility of satellite-derived information in models which describe current and/or potential conditions by testing Geographic Information System capabilities. Testing will include a coastal land capability application, which defines the resource problem(s) being addressed, the data base requirements, and the Geographic Information System requirements to be tested. In addition, the management information requirements are listed with the evaluation criteria.

During FY1982, data base construction was initiated for each of the Gulf Coastal Plain test sites and will continue during FY1983. Thematic Mapper Simulator (TMS) data were also acquired over each test site for analysis during FY1983 with Thematic Mapper (TM) data analysis scheduled for FY1984.

The general approach described for the Gulf Coastal Plain will be employed for each major test area. The differences lie in the technology required to address the environmental and cultural characteristics and corresponding resource issues unique to each area.

STRUCTURE OF COASTAL LANDS CAPABILITY TEST



SOUTHERN APPALACHIAN HIGHLANDS

The southern portion of the Appalachian Highlands area encompasses portions of 5 states characterized by 3 major physiographic provinces: (1) the Blue Ridge/Unaka Mountain system; (2) the ridge and valley province which contains farmland and 3 of the area's largest cities (Knoxville and Chattanooga, Tennessee, and Asheville, North Carolina); and (3) the Allegheny/ Cumberland Plateau. (See figure below.)

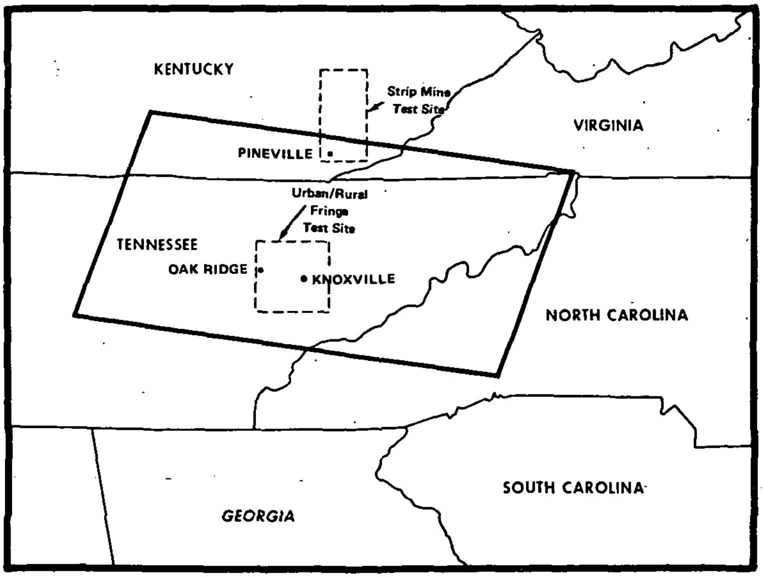
Two primary concerns are conflicts between mined and non-mined lands and the location of areas suitable for residential and industrial development. Surface mining has detrimental impacts on the immediate and surrounding covers. Because strip mining is extensive within the region, it is important to identify areas where mining occurs and to assess the effect this activity has on adjacent land covers or uses. Another problem is encountered at the fringe of urban areas where conflicts between residential or urban development and agriculture are most pronounced. Due to the restrictive terrain, agriculture and urban development are confined primarily to the ridge and valley provinces. Consequently, the land most suited for agriculture is rapidly being acquired by developers for non-agricultural uses.

Accordingly, the emphasis within the Southern Appalachian test area will be site-specific analysis to identify the small heterogeneous features exhibited by surface mines, farming practices, and urban fringe land use patterns within a topographically diverse area. Approaches for extracting information will be placed on thematic analysis for enhanced spectral/ spatial pattern recognition, stratified spectral analysis using ancillary data, terrain analysis, and multisensor data merges (MSS/TM/SAR). In Addition, multidata integration using Geobased Information Systems will address environmental impact assessments and the location of lands suitable for development.

During FY1981, an MSS small feature extraction technique was developed for discriminating small heterogeneous and irregularly shaped surface mines in the mountains of eastern Kentucky. This was accomplished as part of the RTOP 'Land Resources Applied Research" with the results reported in the FY1981 Annual Report and verified during FY1982. This technique proved to be a more useful tool for enhancing the discrimination of surface mines than the conventional data processing methods as documented in NSTL/ERL Report No. 206, "A Technique for Using Multidate Landsat MSS Data to Discriminate Small, Heterogeneous Surface Mine Features in Eastern Kentucky," dated March 1982.

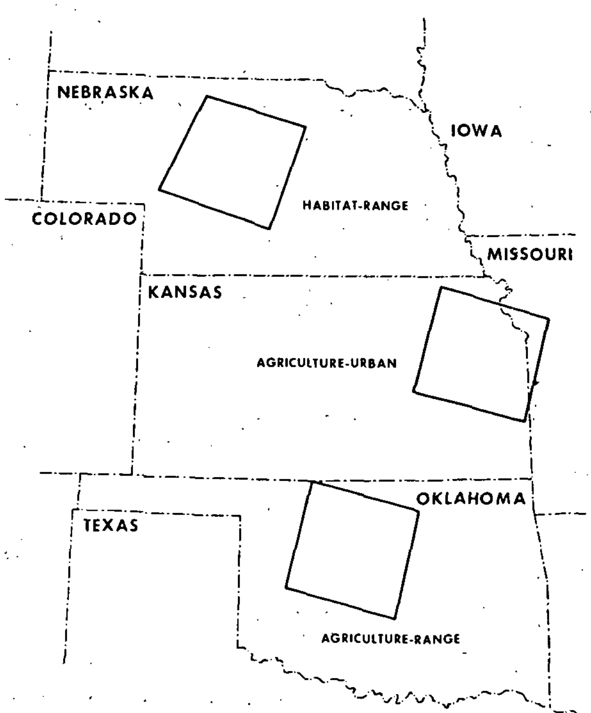
A similar procedure was tested during FY1982 with TMS data over the same area using bands 2, 3, 4, and 5. The results of the TMS analysis, for which the accuracy assessment will soon be completed, appear to considerably improve the discrimination of surface mines when compared with the MSS results. Moreover, discrimination of land cover subunits within the mining areas, such as partially revegetated versus nonvegetated areas, is better defined from TMS data.

SOUTHERN APPALACHIAN HIGHLANDS TEST AREA



During FY1982 the small feature extraction technique will be tested with MSS and TMS data for applicability in western Kentucky where the land is flat or rolling, and the surface mining practices are different. In addition, Knoxville, Tennessee, has been selected as a test site to further evaluate and expand the application of the existing small feature extraction techniques. Knoxville lends itself particularly well to the identification of lands at the rural/urban fringe because agricultural lands within the Southern Appalachian Highlands are small and spatially heterogeneous. These areas of diverse but discrete land covers will provide an opportunity to determine how well satellite-acquired data can produce thematic maps of unique land covers and uses at the rural/urban interface.

INTERIOR PLAINS TEST AREA



INTERIOR PLAINS

Three test sites (see figure below) have been selected in the Interior Plains. The Interior Plains encompass a typical grassland foundation where grasses are climax dominants over a vast area extending from southern Saskatchewan to eastern Texas. The mixed grass prairie is a major ecosystem with vegetation represented by short and tall grasses with the dominant species derived from these components. The Nebraska Sand Hills area provides the exception with a unique ecosystem of tall grass species and freshwater wetlands.

The generally favorable climatic, topographic, and soil conditions of the Interior Plains have resulted in large areas being placed under cultivation for dryland and irrigated farming. In addition, livestock grazing represents a critical land use within the region. Together, agriculture/grazing land use patterns and the urbanization needed to support these activities have continued to reduce the areas available for wildlife.

Critical issues indicative of the region include: loss of prime agricultural lands; allocation of water and loss of soil resources as marginal lands are utilized; and competition between crops, livestock and wildlife requirements. Based on regional diversity and dynamics, the technical emphasis will focus on MSS/TM spectral/sequential analysis techniques of transformed data sets, stratification methodologies for improved crop type discrimination, spatial (contextual/textual/shape) classifiers, and change detection. Three test areas within the Interior Plains have been selected to address these issues.

During FY1982, the Landsat MSS land cover classification baseline was completed for the Habitat-Range test site in Nebraska as part of a cooperative regional applications project with the Nebraska Game and Parks Commission (GPC). In order to improve the monitoring and management techniques of such a vast area, the GPC is assessing the potential of satellite remote sensing techniques in determining the location, quantity, and quality of wildlife habitat types.

In addition, MSS classifications for the Agriculture/Urban (Kansas) and the Agriculture/Range (Oklahoma) test sites were completed in FY1982 as a part of the AgRISTARS Conservation Inventory Project discussed elsewhere in this report.

Since Cherry County includes most of the habitat types that occur wihin the 20,000-square-mile Sand Hills region, the Landsat MSS-derived land cover information provides an assessment of overall range condition. Rangeland classes depicting native grasses by pounds per acre, both dry and subirrigated meadows, blow outs, wetland marsh areas, and forest density classes were classified for their relative value as wildlife habitat. The classification of a single MSS data set was utilized employing the automatic signature development (SRCH) program with the distance parameter set to maximize spectral separation. Further tests with Landsat TM data to improve rangeland condition and species identification are currently being investigated as a potential (FY1983) cooperative Waterfowl Nesting Quality Assessment with Ducks Unlimited, U.S. Fish and Wildlife Service, and the Nebraska GPC.

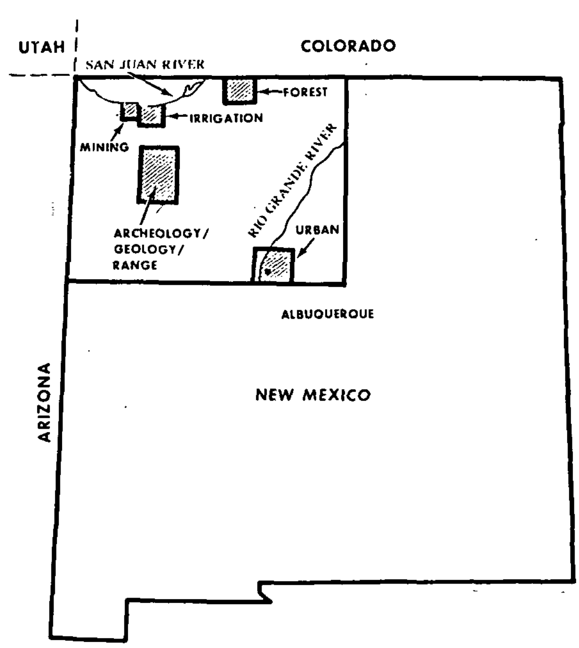
SOUTHWEST SEMI-ARID LANDS

A 2 by 3 degree area in northwestern New Mexico has been selected as the test area within the Intermontane Plateau physiographic region. The test area is a topographically diverse region containing desert basins, the southern section of the San Juan mountains, and an expanse of the Colorado Plateau. The area is interspersed with deep canyons and dry washes, steep mesa breaks, and canyon walls. Annual precipitation increases from a minimum of 8 inches in the basins to a maximum of 40 inches in the higher altitudes. Sparse grasses and shrubs vegetate much of the basin and plateau region; alpine forests and grasses occur in the mountains.

The San Juan Basin alone contains over 53% of the nation's uranium reserves, 5.9 billion tons of strippable coal, 121.8 billion tons of minable coal, and significant oil and gas reserves. In addition to extensive mineral deposits, the area also encompasses the largest surface strip mine in the world, the Navajo 110,000 pivot irrigation project which is currently under development, the largest concentration of prehistoric ruins in North America, large stretches of open grazing land, and rural settlements with few metropolitan areas. (See figure below.)

Competing demands for renewable and non-renewable resources and the impact of large area development represent major issues in the region. When mandated requirements to preserve the cultural integrity of the area are integrated with and are prime restrictions to these issues, alternatives become increasingly complex and costly.

SOUTHWEST SEMIARID LANDS TEST AREA



Emphasis for the application of satellite data acquired over the test area will be large area inventory and monitoring of land disturbances with analysis focused on the thermal and microwave regions of the spectrum, spatial analysis techniques classifiers, and change detection techniques. In addition, test and evaluation activities will address high-speed data processing and storage requirements as well as other sensor data, i.e., NOAA's Advanced High Resolution Radiometer (AVHRR).

Two tests are currently under investigation for possible initiation within the Southwest Semi-Arid Lands test area during FY1983. The first addresses the determination of range biomass. This test will incorporate MSS and TM information extraction techniques developed as part of the Arid Lands Study and presented elsewhere in this report. The results of these techniques will be compared to other methods of data classification and analysis. The second test will use the land cover information developed in the above range study to support an archeological clearance survey thereby avoiding development delays or destroying a significant archeological site. The National Park Service is currently developing a data base which describes and locates by map coordinates each known site in the region. By analyzing site distribution, site type, and environmental variables, it is potentially possible to predict the number and significance of the sites that will require archeological clearances in unsurveyed areas.

Current MSS sensor technology potentially meets the requirements for archeological clearance survey modeling. Those remote sensing methods under study in the archeological investigations (presented elsewhere in this report) may considerably enhance the application of future technology for systematic and intensive archeological inventories. Such applications would be advantageous to both archeologists and developers. Archeologists would benefit by prioritizing areas for investigation and selecting the most potentially productive areas for extensive and thorough excavation, while industrial, commercial, and residential developers would be able to avoid costly delays.

ADDITIONAL TECHNOLOGY EVALUATION ACTIVITIES

Activities conducted under NSTL/ERL's Regional Applications, Application Systems Verifications and Test (ASVT), and User Requirements programs were completed during FY1982.

TEST AND EVALUATION

As part of the User Requirements program, Sally Bay Cornwell, Inc., conducted a Local Needs Assessment which identified the critical resources issues currently facing planners and managers at the substate/local levels of government and the resource information requirements that are required to address these issues. A preliminary assessment published in January was reviewed by a network of 125 organizations and individuals across the country who were requested to specify their particular area of concerns, information required, and how NASA, through its R&D program, might address these requirements with satillite-related technology. The findings of the assessment were reported at the 1982 Urban Regional Information System Conference in Minnesota this August, and the final report, "Local Needs Assessment: Research Required for Local Resource Decisions in the 1980's," will be available in the first quarter of FY1983.

Regional Landsat MSS Application projects completed this year include Land Use Studies with the Arkansas Geological Commission; a Soil Erosion Hazard Assessment with the Missouri Department of Conservation; Irrigated Lands (Phelps County) and Rangeland Condition Assessment (Cherry County) with the Nebraska Natural Resources Commission and the Game and Parks Commission; and a Land Loss Assessment with Lafourche Parish, Louisiana, through Louisiana State University. (See plates 18 & 19.) In addition, the Water Resources Management ASVT project with 4 Florida Water Management Districts was completed during FY1982. Project accomplishments include land cover classifications within the 4 Water Management Districts and the associated accuracy assessments.

The final test to be completed during the project was the Kissimmee River Basin located within the South Florida Water Management District which serves as an example of the issues facing water resource managers in Florida. The Kissimmee River flows between Lake Kissimmee and Lake Okeechobee in south-central Florida and has been a source of controversy since the water course was channelized in the 1950's. Diminishing wetlands and wildlife habitats in this region have prompted state conservation officials to explore alternatives to the present channel configuration. South Florida Water Management District officials are currently comparing their conventional land use mapping techniques with Landsat-derived land cover information.

During FY1982, Suwannee River WMD completed a field test of a NASA/ERL-developed analysis system based on the 8-bit microprocessor. As a part of the test, updates of prior land cover classifications of Suwannee Sound and Alachua County, Florida, were conducted with 1981 Landsat data. District managers also conducted a survey of regional, county, and municipal resource management agencies to determine the types of information required to deal with resource management problems and how these problems might be addressed with microprocessor technology.

Project documentation will be available in December, 1982. However, a major accomplishment of the ASVT project is the implementation of Landsat technology into state and substate resource management programs within the State of Florida. The Florida Department of Natural Resources has purchased an information system for conducting coastal lands research. Suwannee River WMD has installed a Geographic Information System for correlating water resource data with land use planning activities. Southwest Florida WMD and the Florida Department of Transportation have been funded for Landsat-based Geographic Information System acquisition.

APPENDIX

Page intentionally left blank

Page intentionally left blank

For additional information on the topics previously discussed, contact the authors listed below.

SENSOR SYSTEMS - G.F. Flanagan, HA41, 688-3588

Thematic Mapper Simulator
Thermal Infrared Multispectral Scanner
Advanced Sensor Design Studies

DATA ANALYSIS PROGRAMS

Automatic Segment Matching Algorithm - M.T. Kalcic, HA42, 688-1931
Contextural Information Classifer - M.T. Kalcic, HA42, 688-1931
Geobased Information System - B.G. Junkin, HA42, 688-1926

AgRISTARS

Land Cover Area Estimation - Dr. E.R. Stoner, HA10, 688-1921
Land Cover Information System - D.A. Quattrochi, HA30, 688-1919
Geographic Information Systems - D.A. Quattrochi, HA30, 688-1919
Land Cover Change Detection - G.S. Burns, HA10, 688-1911
Map Product Accuracy - J.E. Anderson, HA20, 688-1909
Thematic Mapper Procedure Development - J.E. Anderson, M.K. Butera, HA10, 688-1912
Conservation Inventory - Dr. R.H. Griffin, HA10, 688-1915
SAR Procedure Development - Dr. S.T. Wu, HA20, 688-1922

APPLIED RESEARCH AND DATA ANALYSIS

Monitoring of Rangeland Degradation - Dr. H.B. Musick, HA10, 688-1918
Discrimination of Small Mine Features - D.A Quattrochi, HA30, 688-1919
Soil Delineation Research - Dr. E.R. Stoner, HA10, 688-1921
Archeological Investigation - T.L. Sever, HA30, 688-1906
Fundamental Research: Scene-to-Map Registration - Dr. D.D. Dow, HA20, 688-1914
Interface Measuration Techniques - Dr. D.D. Dow, HA20, 688-1914
Interface Length - Dr. D.D. Dow, HA20, 688-1914
Non-Renewable Resources Geological Mapping - Dr. D.L. Rickman, HA20, 688-1929
Geobotanical Applications - Dr. W.G. Cibula, HA20, 688-1913
Microwave Sensor Analysis - Dr. S.T. Wu, HA20, 688-1922

JOINT RESEARCH PROJECT

Crop Mensuration and Mapping - D.P. Brannon, HA30, 688-2043
Timber Resources Inventory - C.L. Hill, HA30, 688-2047
Wetlands Productive Capacity Modeling - M.K. Butera, HA10, 688-1912
Farmers' Information and Resource System - Dr. E.R. Stoner, HA10, 688-1921
Cotton Acreage Inventory - Dr. R.H. Griffin, HA10, 688-1915

TEST AND EVALUATION - P.K. Conner, HA30, 688-2042

Southern Test and Evaluation Program (STEP)
Gulf Coastal Plain
Southern Appalachian Highlands
Interior Plains
Southwest Semi-Arid Lands
Additional Technology Evaluation Activities

APPENDIX

PAPERS

- Evaluation of Land Cover Change Detection Techniques Using Landsat MSS Data, by Gregory S. Burns and Armond T. Joyce. Presented at: Pecora VII Symposium, Sioux Falls, South Dakota, October 1981.
- Utilization of Principal Components Analysis and Band - Ratioing for the Discrimination of Surface Mines from Landsat MSS Data, by Dale Quattrochi. Presented at: Association of American Geographers Annual Convention, San Antonio, Texas, April 1982.
- NASA's Thematic Mapper Simulator, by G.F. Flanagan and E.L. Tilton, III. Presented at: IGARSS 1982 Symposium, Munich, Germany, June 1982.
- Remote Sensing of Wetlands, by M.K. Butera. Presented at: IGARSS 1982 Symposium, Munich, Germany, June 1982.
- Multisensor Data Analysis and its Application of Monitoring of Croplands, Forest, Strip Mines, and Cultural Targets, by Dr. S.T. Wu. Presented at: Eighth International Symposium of Machine Processing of Remote Sensing Data, July 1982.
- Agricultural Land Cover Mapping with the Aid of Digital Soil Survey Data, by E.R. Stoner. Presented at: 1982 Machine Processing of Remotely Sensed Data Symposium, Purdue University, West Lafayette, Indiana, July 1982.

PUBLICATIONS

- An Algorithm for Automating the Registration of USDA Segment Ground Data to Landsat MSS Data, by M.H. Graham. AgRISTARS Report DC-Y1-04211, December 1981.
- Analysis of Thematic Mapper Simulator Data Acquired During Winter Season Over Pearl River, MS, Test Site, by J.E. Anderson and M.T. Kalcic. AgRISTARS Report RR-Y1-04217, March 1982.
- A Technique for Using Multidate Landsat MSS Data to Discriminate Small, Heterogeneous Surface Mine Features in Eastern Kentucky, by Dale A. Quattrochi. ERL Report No. 206, March 1982.
- Agricultural Land Cover Mapping in the Context of a Geographically Referenced Digital Information System, by E.R. Stoner. ERL Report No. 205, March 1982.
- Thematic Mapper Simulator Data Collected Over Eastern North Dakota, by J.E. Anderson. AgRISTARS Report DC-Y1-04232, April 1982.
- SLIN - A Software Program to Measure Interface Length, by David D. Dow and Ronnie W. Pearson. ERL Report No. 208, April 1982.
- Analysis of Data Acquired by Synthetic Aperture Radar and Landsat Multispectral Scanner Over Western Kentucky Coal Region, by S.T. Wu. ERL Report No. 207, May 1982.
- Characteristic Variations in Reflectance of Surface Soils, by E.R. Stoner and M.F. Baumgardner. Purdue University, West Lafayette, Indiana, AgRISTARS Report SR-P2-04301, May 1982.
- Extension of Laboratory - Measured Soil Spectral to Field Conditions, by E.R. Stoner, M.F. Baumgardner, R.A Weismiller, L.L. Biehl, and B.F. Robinson. Purdue University, West Lafayette, Indiana, AgRISTARS Report SR-P2-04326, June 1982.
- Landsat-D Thematic Mapper Simulator, by E.L. Tilton, III and G.F. Flanagan. June 1982, Munich, Germany - 1982 IGARSS.
- NASA: Present State and Future Plans for Remote Sensing Technology, by D. Wayne Mooneyhan. July 1981, in Bogota, Columbia.
- Software Programs to Measure Interface Complexity with Remote Sensing Data, with an Example of a Marine Ecosystem Application, by David D. Dow. ERL Report No. 210, August 1982.
- The Contribution of Remote Sensing to Information System Development, by E.L. Tilton, III. September 1982, in Mexico City, MX - II Congress VII Panamerican National Congress.
- Analysis of Dry Season Thematic Mapper Simulator and Landsat Multispectral Scanner Data for Jornada Test Site, by H.B. Musick. ERL Report No. 211, November 1982.
- Determining Map Accuracy Based on the use of USDA Statistical Reporting Service June Enumerative Survey Segment Data, by J.E. Anderson. ERL Report No. 216, December 1982.